Reviewer 1

Comments on " Role of wind, mesoscale dynamics and coastal circulation in the interannual variability of South Vietnam Upwelling, South China Sea. Answers from a high resolution" by Tai To Duy et al. in Ocean Science

In this study, the authors attempted to explore the dynamics governing the interannual variability of South Vietnam Upwelling based on model simulation. Befere discussing the modelling results, they first compared the general patterns of simulated SST, SSS, and SLA with the satellite-remosed data, and compared the simulated temperature and salinity profiles with the in-situ measturements of ARGO, Seaglider, and R/V cruise. After reviewing, I think the manuscript needs an subsustainsial revision before being acceptable based on the following comments.

We warmly thank the reviewer for this careful and constructive review of our paper. We addressed all the comments below in our revised version of the manuscript. In this document, the reviewer's comments appear in black, and our answers in green. Changes done in the manuscript following the comment of the reviewer are also highlighted in green in the revised version of the manuscript. Line numbers and pages in this document refer to the highlighted version.

Major Comments:

1. Methodology:

a) The authors explored the South Vietnam Upwelling in four areas: BoxOF, BoxNC, BoxSC, and BoxMK. For the first three areas, the cold temperature are evident in both the simulated SST and satellite SST. However, for the BoxMK, the cold temperature seems only appear in simulated SST, but not in satellite SST, althougth the authors have referred to the finding of two literatures. This argument does not make sense, because a reader cannot directly confirm the rationality of considering BoxMK a spereate area to be explored. If this is not a natural phenomenon, the discussion becomes meaningless.

Indeed, though upwelling in the southern (BoxSC) and northern (BoxNC) coastal areas and in the offshore area (BoxOF) was already mentioned and studied in previous studies (see for example *Da et al. 2019, Ngo and Hsin 2021*), no mention of an upwelling appearing offshore the Mekong Delta (BoxMK) was previously mentioned. A careful examination below of analysis products, satellite data and available in-situ data over the area shows that this can be explained by the scarce satellite and in-situ cover of upwelling that occurs over this small area and the smoothing associated with analysis construction.

OSTIA level 4 analysis SST data are indeed built combining complementary satellite and in situ observations within Optimal Interpolation systems on a global 0.054 degree grid (*UK Met Office. 2005*). This Optimal Interpolation induces spatial and temporal smoothing of extreme values. Similarly, the COPERNICUS PSY4QV3R1 analysis is produced using a 1/12° ocean model that assimilates available satellite and in-situ data, and does not include tide.

The satellite and in-situ coverage of the SVU area in summer is not very good, due to the high cloud cover. It is all the more the case of the small BoxMK area. We can examine this availability in JAXA satellite data : we use the daily SST (Level 3) dataset provided from Himawari Standard Data by JAXA over the period 2015 - present with a 2 km spatial resolution. For summer 2018, a summer of very strong upwelling, we show the percentage of days during which JAXA data are available in Figure A below. This percentage never exceeds ~85% over the SCS, it is about 75-80% over the offshore VNU region, and it is lower than 60% offshore the Mekong mouth in the area were MKU occurs (and over the Gulf of Tonkin and Gulf of Thailand). For those reasons, the surface cooling over BoxMK may not be correctly captured in analysis data, as we will see below.

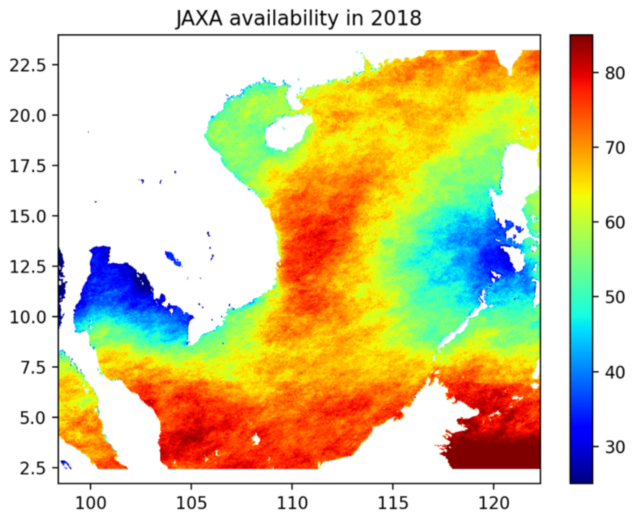

Figure A : percentage of days during which JAXA data are available with a quality level equal or higher than 4 during summer 2018.

Examining directly in-situ and raw satellite data that cover the BoxMK region during the period of upwelling shows that surface cooling indeed occurs over BoxMK at the same time and places as simulated by our model:

→ Summer 2014 : RV Alis crossed BoxMK during 25-26 June 2014. Figure B(left) below shows a zoom of ALIS SST data offshore the Mekong mouth, with a very good agreement between simulated and observed data. In particular, a surface cooling over BoxMK was clearly observed by ALIS-TSG, and simulated by the model, with values of minimum SST ~28.2°C near Con Dao Island (~106.6°E-8.6°N) on 25/06/2014. In-situ data therefore confirm the reality of MKU simulated in SYMPHONIE. Figure B(right) shows the maps of SST from SYMPHONIE, OSTIA and COPERNICUS on 25/06/2014. OSTIA and COPERNICUS actually show a significant surface cooling in the same area as SYMPHONIE, with SST < Tref=29.2°C. However, as explained above, smoothing and data availability result in weaker surface cooling in those analysis products, with minimum SST not going below ~28°C, vs. ~27.5°C in SYMPHONIE.

Figure C,a below shows the daily time series of minimum SST over BoxMK for SYMPHONIE, OSTIA and COPERNICUS during summer 2014. The 3 times series show similar temporal variations with a minimum end of June – beginning of July, however, minimum SST values over BoxMK are ~1.5°C lower in SYMPHONIE than in OSTIA and COPERNICUS during this period.

→ Summer 2018 : in the 2009-2018 simulation, 2018 is the year with the strongest upwelling over BoxMK (Figure 13 of the revised manuscript). Figure C,b below shows the daily time series of minimum SST over BoxMK for SYMPHONIE, OSTIA, COPERNICUS and JAXA satellite data during summer 2018. Again, time series are following similar variations in OSTIA, COPERNICUS and SYMPHONIE, but with much lower values (by ~1.5°C) in SYMPHONIE. Moreover, values simulated in SYMPHONIE are very close to values observed from JAXA satellite data, with peaks at the same period: minimum values of SST are obtained first during mid-June (~26.6°C), mid-July (~25.6°C) and mid-August (~26.2°C).

Figure D shows the SST maps during those 3 upwelling peaks (June 20th, July 16th, August 14th) for JAXA, OSTIA, COPERNICUS, and SYMPHONIE. A surface cooling over BoxMK is clearly visible in JAXA and SYMPHONIE during those MKU peak periods, with SST < 28°C. Again, as observed for 2014, a surface cooling is also produced by OSTIA and COPERNICUS analysis, but with warmer values. OSTIA also produces a strong surface cooling during mid-July with minimum SST reaching ~27.5°C.

Last, surface cooling is stronger in JAXA and SYMHONIE, but, both 2014 and 2018, the area of cooling over BoxMK is very similar in SYMPHONIE and in analysis data (OSTIA and COPERNICUS).

Those results show that upwelling really occurs over BoxMK in summer. It is captured by ALIS TSG in-situ data and JAXA satellite data, and simulated accordingly by SYMPHONIE. They moreover confirm that the corresponding surface cooling is also captured by OSTIA and COPERNICUS, but is strongly smoothed. These results therefore highlight the added-value of a high resolution (~1 km at the coast) resolution model to simulated and study the upwelling in the SVU area, able to simulate better the spatial and temporal fine scale structures of SST compared to coarser resolution gridded satellite data.

→ Following this comment, we added a whole section (**Section 3.1 Upwelling over BoxMK, page 9**) and **Figures 4, 5, 6** to discuss this point this in our revised version of the manuscript

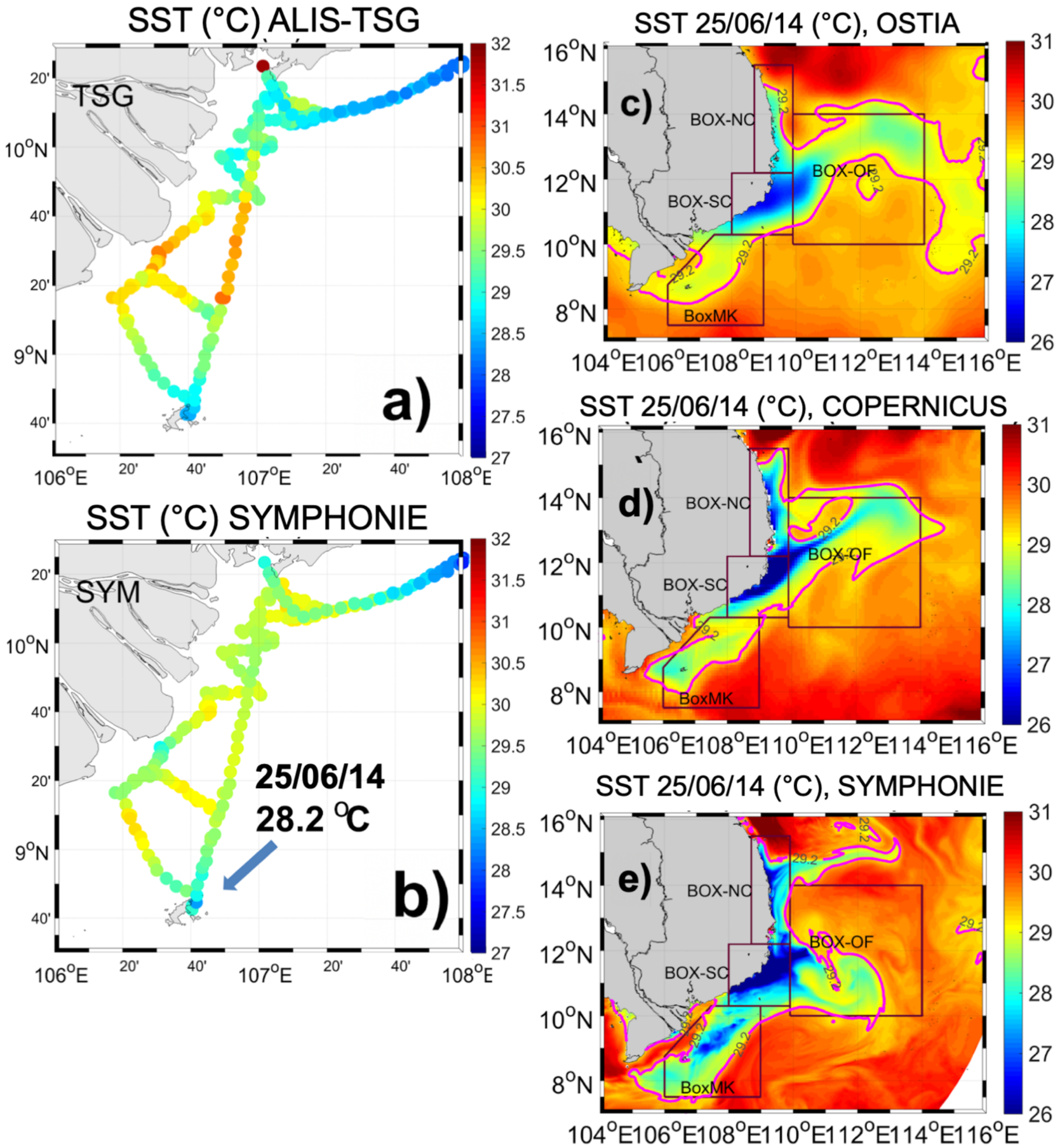

Figure B : Left : Simulated (SYMPHONIE) and observed (ALIS-TSG) SST (°C) during ALIS R/V trajectory offshore the Mekong mouth in June 2014. The arrow shows the location of minimum SST~28.2°C in both data and model, recorded near Con Dao Island (~8.6°E – 106.6°E) on 25/06/2014. Right : SST in June over BoxMK on 25/06/2015 (°C) from SYMPHONIE, OSTIA and COPERNICUS. The pink contour shows the isotherm Tref (=29.2°C, see answer to comment about Tref below).

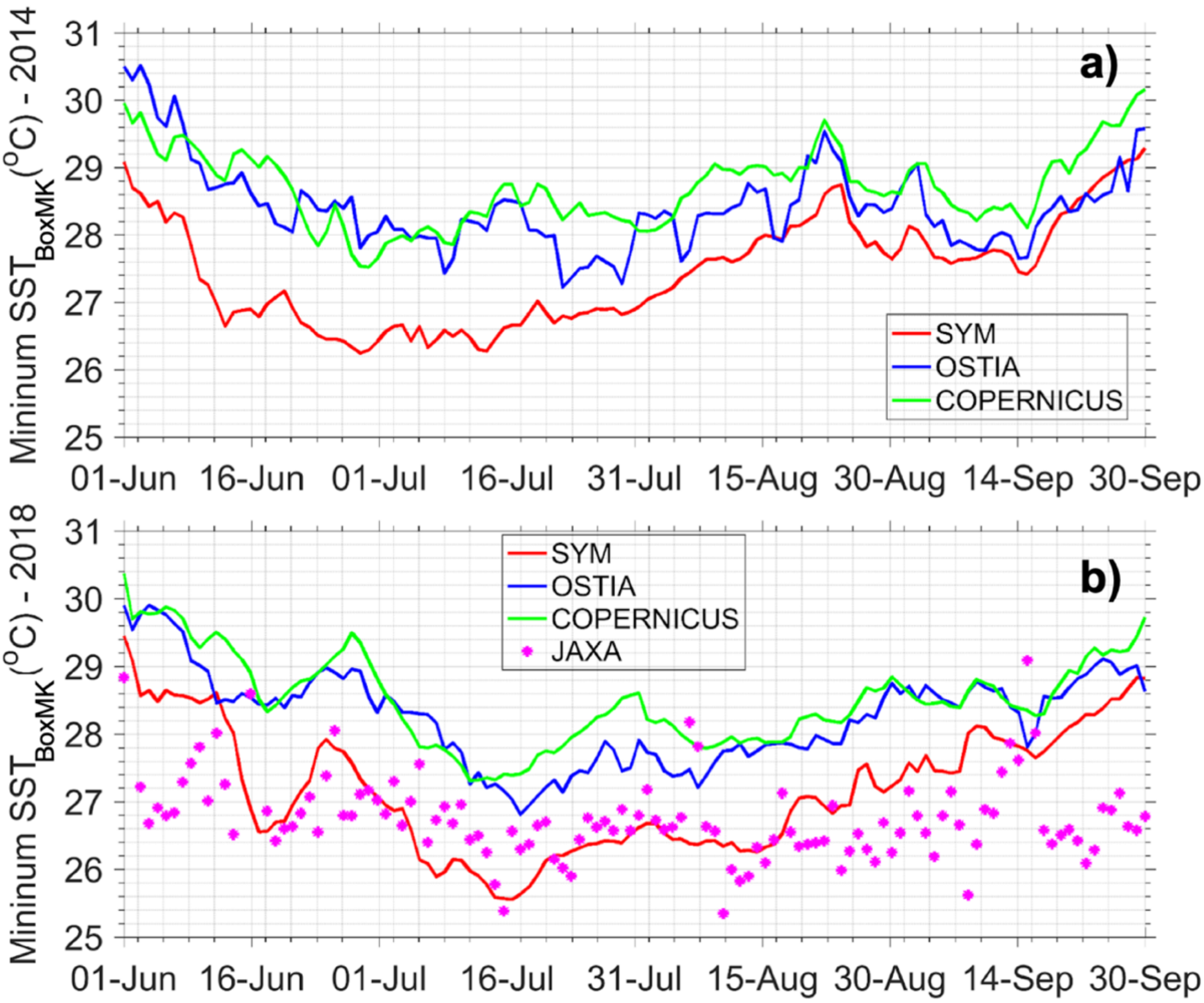

Figure C : Daily time series of minimum SST (°C) over BoxMK in (a) SYMPHONIE, OSTIA, COPERNICUS during summer 2014, and in (b) SYMPHONIE, OSTIA, COPERNICUS and JAXA during summer 2018.

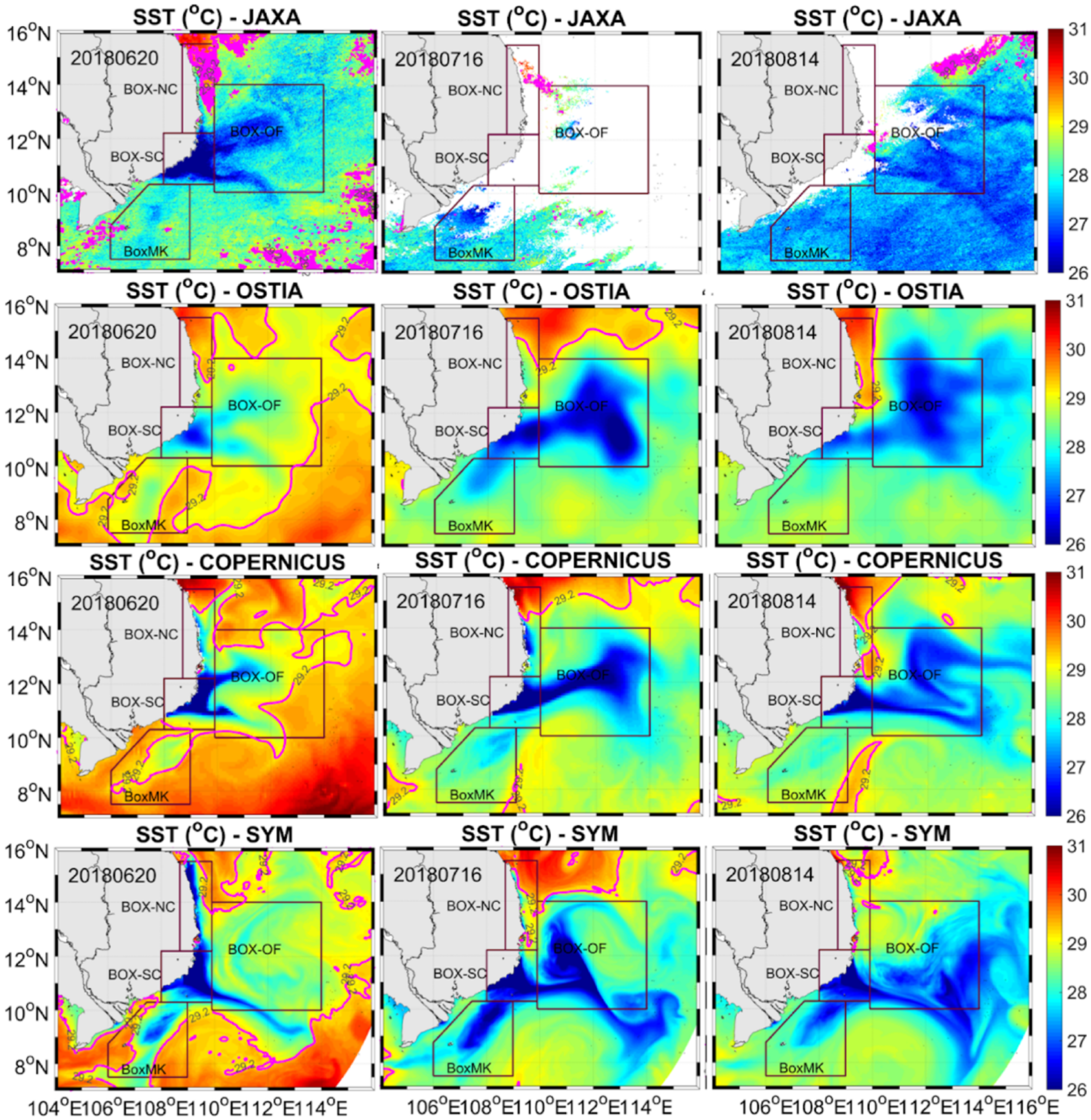

Figure D : Daily SST (°C) on 20/06, 16/07 and 14/08/2014 from JAXA, OSTIA, COPERNICUS and SYMPHONIE. The pink contour shows the isotherm Tref (=29.2°C).

b) The authors performed the simulation of the model SYMPHONIE from 2009-2018 by comparing output data (SST, SSS, SLA, and T-S profiles) with high-resolution satellite data and in-situ observations, showing that this model is an innovative tool that can reproduce oceanic dynamics properly not only at the surface but also at deeper sub-layers, and at wide-range time scales. To investigate the daily-to-interannual variability of the VNU, however, they employed only the surface data (SST and velocity) and the discussions are all statistically, which brings not many new results in the comparison with previous studies using satellite data. In other words, this study can be performed by the satellite data without SYMPHONIE. I think the authors should utilize the advantage of modelling to conduct numerical experiments to examine whether the proposed factors are really factors controlling the interannual variablility of South Vietnam Upwelling in each area.

Indeed, the goal of our work is 1) to develop a high resolution model implemented over the SVU for the study of the upwelling dynamics and variability and to evaluate and show its quality by extensively comparing it with available in-situ and satellite observation ; 2) to investigate the interannual variability of the SVU, confirming results from previous studies made at lower resolution, and going further by investigating 4 different areas at very high resolution ; and 3) to perform sensitivity experiments to further explore the different physical processes and scales of variability involved in the SVU. For this 3rd step, we already conducted several numerical experiments, including ensemble simulations, to investigate the contribution of different factors to the daily to yearly variability of the upwelling: wind, tides, rivers, ocean intrinsic variability (*Da et al. 2019, Li et al. 2014* indeed suggested the importance of those factors). The results of those experiments were presented in the PhD manuscript of To Duy Thai (*To, 2022*). In the present paper, we presented steps 1) and 2). For the sake of conciseness and clarity, we did not present results from step 3) : for that, a second paper is in preparation and will be submitted soon to the same journal. The reviewer writes that "they employed only the surface data (SST and velocity) and the discussions are all statistically, which brings not many new results in the comparison with previous studies using satellite data. In other words, this study can be performed by the satellite data without SYMPHONIE". Our study however contains several elements which make it, in our opinion, a valuable contribution to the understanding of SVU interannual variability. To our knowledge, the most recent and complete studies up to date about the interannual variability of the SVU were done by *Da et al. 2019* and *Ngo and Hsin 2021*. Here are the new elements provided by our study:

- In terms of methodology: we use a very high-resolution numerical model (1 km at the coast to 4 km offshore, and including tides). *Da et al. 2019* used a 14-years 1/12°(~9 km) resolution simulation, not including the effect of tides. *Ngo and Hsin 2021* used ¼° (~28 km) resolution datasets of 38-years SST and reanalysis winds and 28-years satellite-altimeter derived sea surface current. We showed above that the resolution and smoothing associated with analysis data prevent them from fully capturing the signature of upwelling, especially this related to small scales. Our simulation allows to capture, and study, much more accurately the spatial and temporal variations of SST, currents and upwelling than those previous studies.
- In terms of knowledge of the area of development of the SVU over BoxMK (see answer to comment above): our model revealed that upwelling also occurs offshore the Mekong mouth (BoxMK). A careful examination of satellite data and analysis products confirmed that this upwelling over BoxMK is real, but that analysis data can not capture well this upwelling (see answer to the specific comment about MKU above). These results therefore highlight the added-value of a high-resolution model to represent and study the upwelling in the SVU area, able to simulate better the spatial and temporal fine scale structures of SST compared to coarser resolution gridded satellite data.
- In terms of knowledge of the functioning of upwelling over BoxNC : our model revealed that NCU is not primarily driven by the intensity of the summer wind over the SVU of BoxNC region, but rather by the submesoscale scale dynamics that develop over BoxNC (see answer to comment below about BoxNC). This conclusion is a new finding that was obtained thanks to the high-resolution coverage of this small coastal area by our model. Role of submesoscale dynamics in the development and daily to yearly variability of MKU will be examined in further details in the paper in preparation mentioned above.

→ following this comment, we highlighted in the text in more details the added-value of our study regarding those aspects : high-resolution methodology, better representation of fine scale structures of SST and currents over the coastal areas, in particular BoxMK and BoxNC, future studies in preparation to examine more precisely the contribution of different factors. In particular, the Introduction was rewritten in order to better present the existing knowledge about the SVU and its limitations (**lines 70-107**), and the goal of our work regarding the study of contribution of small spatial and temporal scales in the SVU interannual variability (**lines 109-129**). Those aspects were also underlined in the Discussion (**lines 694-715**) and in the Conclusion (**lines 759-756, 774-780, 784-788**).

We also agree that the 3D coverage model can be used to better understand the upwelling, and as explained above we will present in a coming paper results from sensitivity simulations. An important question is in particular whether the surface cooling observed in BoxOF is really the result of an upwelling developing over BoxOF, or of the advection from BoxSC by the eastward jet of cold surface water upwelled at the coast. To answer this question,

Figure F shows the maps of simulated vertical velocity at 20 m, daily upwelling index and surface currents averaged over the two periods of upwelling development in summer 2018 (summer of strongest OFU, Figure 13 of the revised manuscript) : the first two weeks of July 2018 and the first week of August 2018 (Figure 15). Those figures qualitatively show that BoxOF surface cooling indeed partly results from the advection of cold water from BoxSC, in particular in July. However, strong upward (positive) vertical velocities are simulated, not only along the coast and over BoxMK, but also over BoxOF, in particular in August. This confirms that a significant part of surface cooling over BoxOF results from a local upwelling. Further dedicated studies, including box analysis following the method used for dense water formation by Herrmann et al. (2008), are now required : they will help to quantitatively assess the respective contribution of lateral advection, surface forcing, vertical advection and internal mixing to the formation of cold water over BoxOF, and their temporal and spatial variability, in the formation of cold surface water over BoxOF. This kind of analysis is out of the scope of the present paper, but will be developed at the daily scale and presented in a next paper.

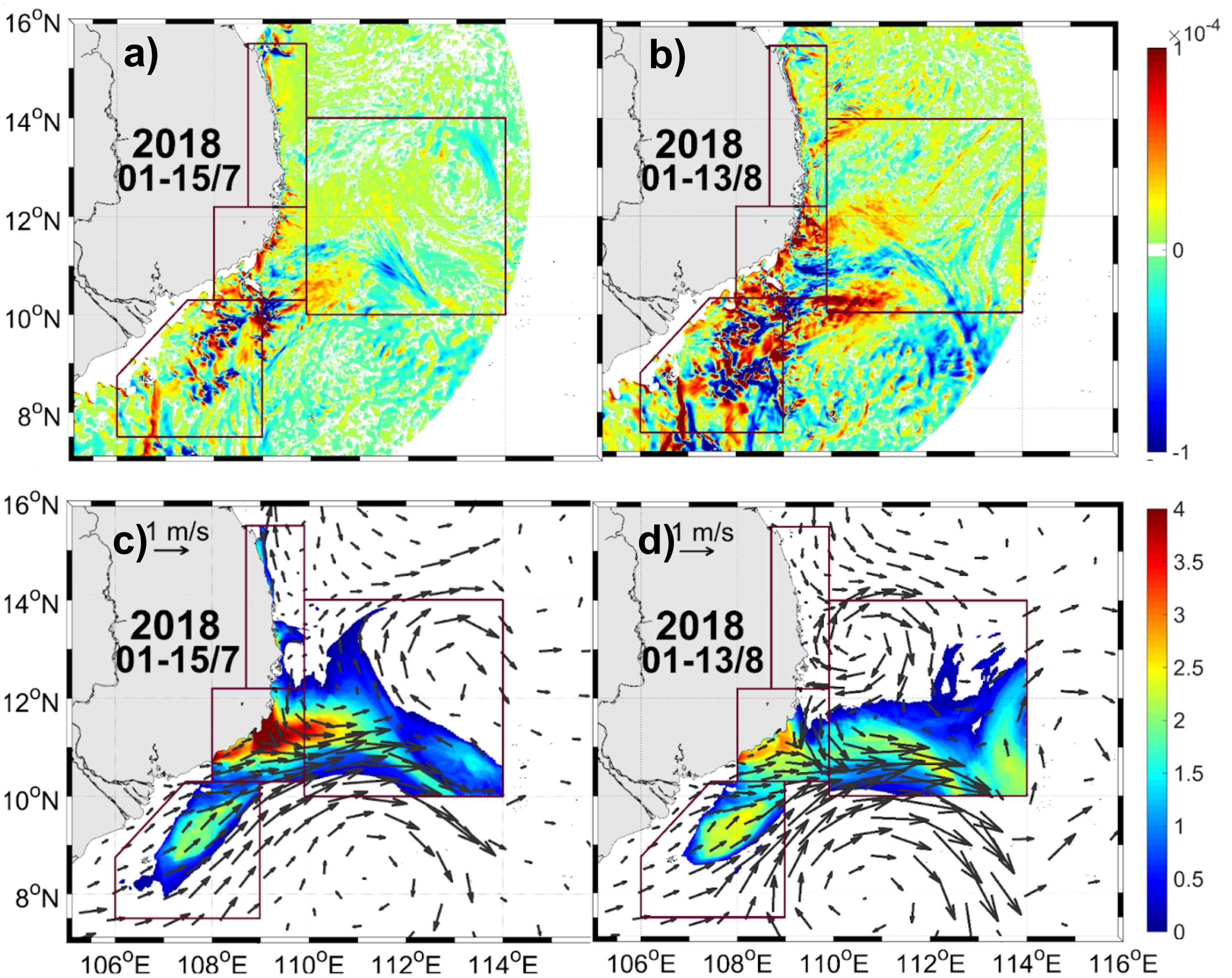

Figure E : Vertical velocity (m.s^{-1}, 1st row) and daily upwelling index (°C, 2nd row) and surface currents (m.s^{-1}) averaged over the July (a,c) and August (b,d) periods of upwelling development in summer 2018.

→ following this comment, we added a new section in the discussion (**Section 5.5. Surface cooling over BoxOK: offshore upwelling vs. lateral advection of cold water**) and **Figure 17**.

c) In Section 2.3, the author introduced several SST-based upwelling indicators (daily, yearly and spatial upwelling index), which are applied for 4 upwelling areas. Each area uses different reference boxes, which is taken as the areas not impacted by surface cooling. However, the boxes (besides RefOF) they chose may be highly possible to be influenced by other upwelling areas. For example, RefNC could be impacted by the offshore upwelling if the offshore upwelling have more northern extension. In addition, the authors use the time-averaged Tref in each Reference box, but the temperature in the SCS suffers interannual variations, e.g., Figure 3b. This could make a great impact on the calculation of SST-UI, and result in a large dependency as discussed in section 4.5.

d) Another concern is that the spatial upwelling index could be not a continuous field as shown in Figure 8 because the authors use different Trefs.

We answer to comment c) and d) together.

First, we completely agree that the SST over the reference boxes chosen for BoxMK, BoxSC and BoxNC may be influenced by the propagation into the reference box of water upwelled in other areas. This is all the more the case when the reference box is small. Moreover, using different Tref makes the upwelling index field spatially discontinuous. We therefore recomputed everything with the same Tref for all the boxes, taking Tref for BoxOF, which can be considered as large and far enough from the upwelling areas. We obtain a value of Tref=29.20°C. Using different boxes, our former values were $Tref_{NC}$=29.66°C, $Tref_{SC}$ = $Tref_{MK}$= $Tref_{OFF}$ 29.20 °C. Except for BoxNC, using different references boxes actually was thus equivalent as using a unique reference box. Note also that even for BoxNC, the difference of upwelling index value induced by the new choice of Tref will be very small. Given the formulae used for UId and UId (Equations 1 and 2 of the revised manuscript, see below), the relative difference between UIy and UId computed using the new and the old Tref will be equal to (Tref,new - Tref,old)/Tref,old = (29.2-29.7)/29.7 = -0.017 ~ -2%).

$$UI_{d,boxN}(t) = \frac{\iint_{(x,y) in\ boxN\ so\ that\ SST(x,y,t)<To} (T_{refN} - SST(x,y,t)).dx.dy}{A_{boxN}} (1) \quad \text{and} \quad UI_{y,boxN} = \frac{\int_{JJAS} UI_{d,boxN}(t)dt}{ND_{JJAS}} (2)$$

Table A below shows the updated values for table 2 of the manuscript. Logically (since Tref only changes for BoxNC, by less than 2%), UIy (mean, std, CV) values do not or only very slightly change. Moreover, most of the correlation values remained unchanged, and those which changed only slightly changed by less than 0.03 (see table A). Our conclusions concerning the relationships between the different factors were robust to this choice of reference temperature.

Table A : Modified Table 2 with a constant and unique Tref=29.2° (values that were modified compared to the previous manuscript are highlighted in red and italics). From 1st to last line : temporal mean and standard deviation of UIy,boxN over 2009-2018 for each box and coefficient of variation CV (which is the ratio between STD and mean), correlations (correlation coefficient and associate p-values) between time series of significant factors : yearly upwelling index over each box vs. yearly upwelling index over other boxes, vs. average wind stress averaged over June-September (JJAS) and July-August (JA) over each box, vs. integrated positive vorticity over BoxOF. Correlations significant at more than 99% (p<0.01) are highlighted in bold.

	BoxNC	BoxSC	BoxOF	BoxMK
$UI_{y,boxN}$ mean (°C)	0.163 *vs. 0.195 (0.14 in the previous manuscript was a typo)*	0.798 *(0.42 in the previous manuscript was a typo)*	0.074 *(0.09 in the previous manuscript was a typo)*	0.065
$UI_{y,boxN}$ STD (°C)	0.118 *vs. 0.14*	0.423	0.093	0.055
CV (%)	72 *vs. 71*	53	126	85
Correlation between	$UI_{y,NC}$	$UI_{y,SC}$	$UI_{y,OF}$	$UI_{y,MK}$
$UI_{y,SC}$ (°C)	0.00(0.99) *vs. +0.01(0.98)*	**1**	**+0.73(0.02)**	**+0.83(0.00)**

$UI_{y,OF}$ (°C)	-0.26(0.47)	**+0.73(0.02)**	**1**	**+0.92(0.00)**
$UI_{y,MK}$ (°C)	-0.19(0.59)	**+0.83(0.00)**	**+0.92(0.00)**	**1**
$WS_{JJAS,NC}$ ($N.m^{-3}$)	-0.09(0.78) *vs. -0.10(0.77)*	-0.41(0.24)	+0.23(0.53)	+0.07(0.85)
$WS_{JJAS,SC}$ ($N.m^{-3}$)	-0.13(0.72)	+0.85(0.00)	+0.76(0.01)	+0.83(0.00) *vs. +0.84 (0.99)*
$WS_{JJAS,OF}$ ($N.m^{-3}$)	-0.19(0.60)	+0.81(0.00)	+0.77(0.01)	+0.80(0.01)
$WS_{JJAS,MK}$ ($N.m^{-3}$)	-0.08(0.81)	+0.78(0.01)	+0.63(0.05)	+0.72(0.02)
$WS_{JA,NC}$ ($N.m^{-3}$)	+0.04(0.90) *vs. +0.07(0.92)*	+0.18(0.62) *vs. +0.12(0.62)*	+0.54(0.11)	+0.38(0.28)
$WS_{JA,SC}$ ($N.m^{-3}$)	-0.15(0.69)	**+0.70(0.03)**	**+0.84(0.00)**	**+0.84(0.00)**
$W_{JA,OF}$ ($N.m^{-3}$)	-0.15(0.67)	**+0.69(0.03)**	**+0.84(0.00)**	**+0.82(0.00)**
$W_{JA,MK}$ ($N.m^{-3}$)	-0.11(0.77)	**+0.72(0.02)**	**+0.78(0.01)**	**+0.82(0.00)**
$\zeta_{+,OF}$ (s-1)	-0.28(0.43)	**+0.60(0.07)**	**+0.69(0.03)**	**+0.74(0.01)**

Second, we chose a constant Tref, as done previously by *Da et al. (2019)*, whereas other studies, like *Ngo and Hsin (2021)*, used an interannually varying Tref, to take into account the fact that SST can also vary on an interannual basis. We completely agree that SST varies interannually. We justify our choice of a constant Tref by the fact that even if the reference box was chosen outside the upwelling area, the SST in this box can be influenced by the eastward advection of water upwelled in the other boxes. This can be seen on Figure F that shows the JJAS map of simulated SST for summers 2010 (year of weakest upwelling) and 2018 (year of strongest upwelling). In 2018, the SST in the reference area is cooler than in 2010 due to the eastward advection of upwelled water. The upwelling index computed from the difference *SST(x,y,t) - SSTref*, would therefore be smaller in 2018 and larger in 2010 using a varying Tref vs. a constant Tref. In other words, a varying Tref would increase the weak values and decrease the strong values, hence reducing the interannual variability. Note however that the impact on weak values is actually limited by the use of the threshold temperature T_0. We investigated the influence of this choice on our results. Figure G shows the time series of Tref computed annually instead of a constant Tref, and the resulting yearly time series of UIy for each box. Table B provides the modified values of Table A. The resulting UIy values slightly vary, in particular for stronger values (see year 2018), but that the change is not significant. The interannual variability remains nearly the same, though it slightly decreases, as expected. Correlation coefficients consequently also slightly decrease (by at most ~0.10). However, correlations that were statistically significant (or not), remain statistically significant (or not). Our conclusions are therefore still valid.

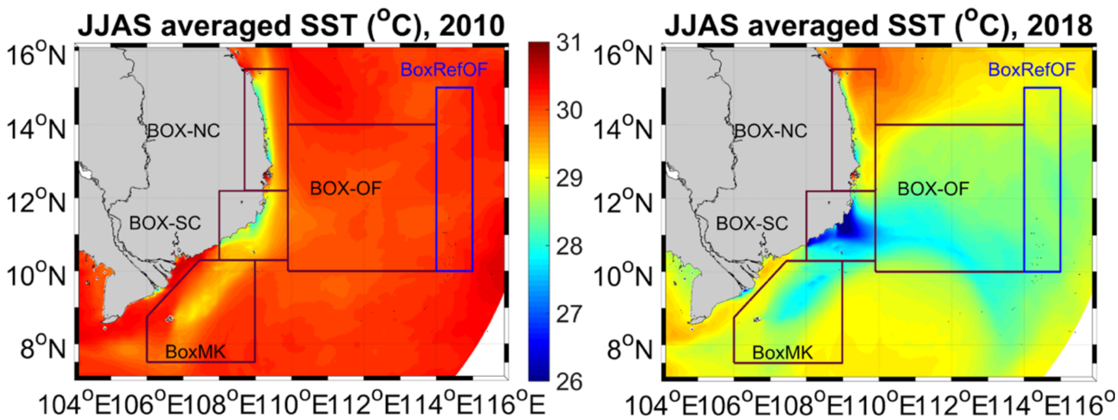

Figure F : JJAS average SST in the 2009-2018 simulation in 2010 and 2018 (°C).

Table B : Modified Table A with a varying Tref (values that were modified compared to Table A are highlighted in red) :

	BoxNC	BoxSC	BoxOF	BoxMK
$UI_{y,boxN}$ mean (°C)	0.171	0.743	0.060	0.055
$UI_{y,boxN}$ STD (°C)	0.140	0.344	0.065	0.040
CV (%)	82	46	108	73
Mean of $\zeta_{+,OF}$ (s^{-1})	1.95×10^{-6}			
Correlation between :	$UI_{y,NC}$	$UI_{y,SC}$	$UI_{y,OF}$	$UI_{y,MK}$
$UI_{y,SC}$ (°C)	+0.11(0.78)	1	+0.63(0.05)	+0.73(0.02)
$UI_{y,OF}$ (°C)	-0.28(0.42)	+0.63(0.05)	1	+0.81(0.00)
$UI_{y,MK}$ (°C)	-0.09(0.80)	+0.73(0.02)	+0.81(0.00)	1
$WS_{JJAS,NC}$ ($N.m^{-3}$)	-0.01(0.97)	-0.43(0.21)	+0.21(0.56)	+0.09(0.80)
$WS_{JJAS,SC}$ ($N.m^{-3}$)	-0.25(0.48)	+0.72(0.02)	+0.77(0.01)	+0.76(0.01)
$WS_{JJAS,OF}$ ($N.m^{-3}$)	-0.30(0.39)	+0.66(0.04)	**+0.77(0.01)**	+0.69(0.03)
$WS_{JJAS,MK}$ ($N.m^{-3}$)	-0.20(0.57)	+0.66(0.04)	**+0.63(0.05)**	+0.65(0.04)
$WS_{JA,NC}$ ($N.m^{-3}$)	+0.05(0.89)	+0.14(0.70)	+0.53(0.11)	+0.30(0.39)
$WS_{JA,SC}$ ($N.m^{-3}$)	-0.23(0.52)	+0.54(0.11)	+0.82(0.00)	+0.73(0.02)
$W_{JA,OF}$ ($N.m^{-3}$)	-0.23(0.52)	+0.53(0.11)	+0.82(0.00)	+0.70(0.03)
$W_{JA,MK}$ ($N.m^{-3}$)	-0.20(0.59)	+0.59(0.07)	+0.77(0.01)	+0.74(0.02)
$\zeta_{+,OF}$ (s^{-1})	-0.37(0.30)	+0.43(0.22)	+0.68(0.03)	+0.64(0.05)

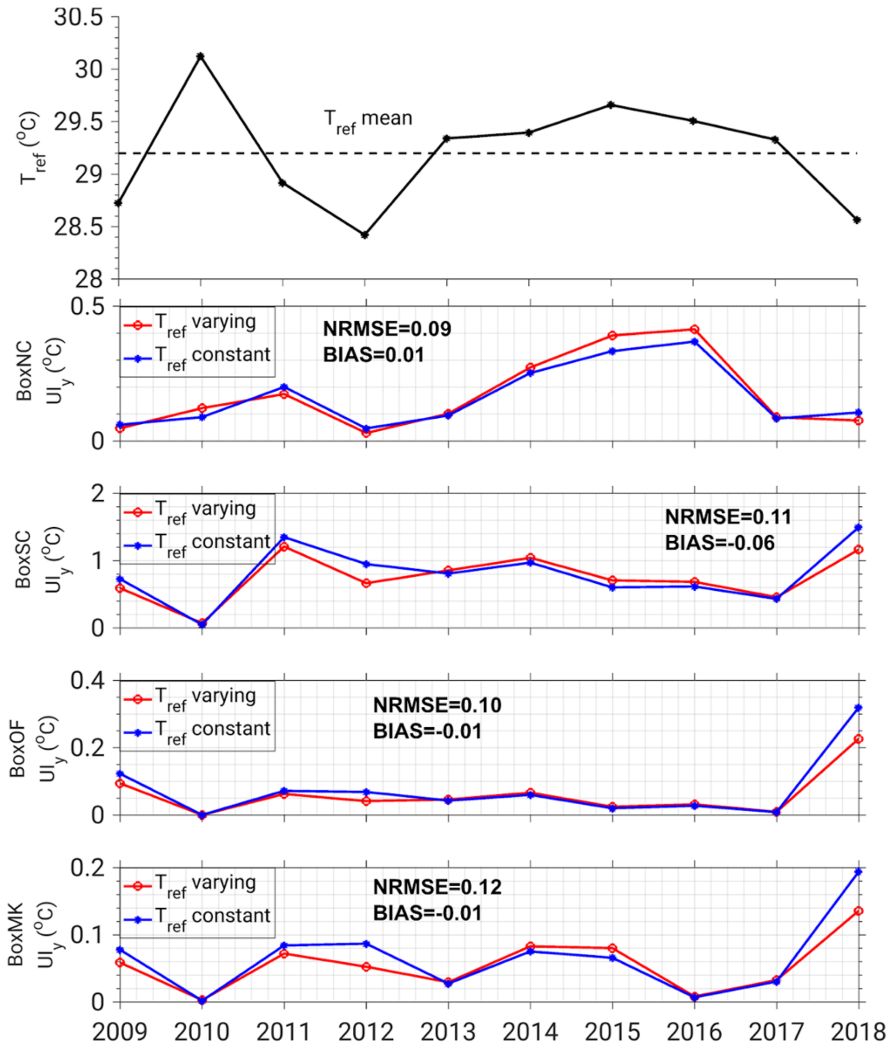

Figure G : (1st row) yearly time series of an interannually varying summer averaged SST over the reference box (=varying Tref, full black line) and value of the climatological summer averaged SST over the reference box (=constant Tref, dashed line). Yearly time series of upwelling indexes UIy computing using a varying (red) vs. constant (blue) Tref, for BoxNC (2nd row), BoxSC (3rd row), BoxOF (4th row) and BoxMK (5th row).

→ Following this comment**, Figures 12, 13, 14, 15, Table 2 of the revised manuscript** were modified after using the same and constant Tref for all boxes. The definition of Tref was modified (**Lines 225-229 in Section 2.3)**. A new section **(Section 5.1, p19)** and a new figure (**Figure 16**) were moreover added to discuss the sensitivity of our results to a varying vs. constant Tref.

e) Some calculations have been done but not defined (i.e. wind stress, vorticity, coefficient of variation, …). Specifically, the authors adopted wind stress for many places, but they did not define the wind stress: meridional wind stress, zonal wind stress, along-shore wind stress or cross-shore wind stress.

Wind stress (taux,tauy) (zonal and meridional components) is computed from ECMWF wind velocity based on the bulk formula of Large and Yeager (2004) : (taux,tau_y) = rhoa sqrt(Cd) (u10,v10)

where *(u10,v10*) is the wind velocity at 10 m height , *rhoa* is the air density computed from sea level pressure *SLP* and air temperature at 2m *T2m* : *rho = SLP / (287,058 T2m),* and *Cd* is the nonlinear drag coefficient computed from Large and Yeager (2004).

The horizontal wind stress curl *WS* is computed as the vertical component of wind stress rotational: $WS = dtau_y / dx - dtau_x / dy$.

Similarly surface current vorticity **ζ** is computed as the vertical component of surface current rotational: $\zeta = dv_{surf} / dx - du_{surf} / dy$.

→ Following this comment we added those definitions in the revised paper (**lines 157-163 in Section 2.1 and 413-416 in Section 4**)

CV is defined as the ratio between STD (row 2 of Table 2) and mean.

→This was explicitly written in the text (**line 418**), and added in **caption of Table 2 (2^nd line)**

2. Result and discussion:

a) The authors wrote long paragraphs to describe known results and few lines for un-solid conclusions. For example:

Section 4.1: The impact of intra-seasonal and inter-annual variability of wind forcing on SCU has been revealed. I suggest the authors r**econstruct this section by referencing known results in the introduction, using several sentences to describe the similarity with previous outcomes and highlighting new finding they have discovered**. In the case of oceanic factors, word usage is not direct to point, for instant, "background coastal circulation" and "mesoscale structure". Qu**antitative assessment is missing for the oceanic factors**.

b) Similar comments for Sections 4.2, 4.3, and 4.4.

→ Following this comment, and the comment of the other reviewer, we developed in the Introduction the part about the existing knowledge about SVU (areas of development, role of wind, eddies and intrinsic ocean variability, **lines 70 to 107**). We also detailed the scope of the present study (**lines 114 to 129)** which fundamental objective is to better monitor, represent and understand the behavior of upwelling at smaller scales (meso to submesoscales), and over detailed areas (coastal to offshore) and the role of high frequencies (daily to intraseasonal). In **Sections 4.2 to 4.5**, we highlighted:

- what was a confirmation of previous results (those parts were strongly reduced, and previous results were described in the Introduction): **lines 452-461 for SCU, 498-509 for OFU,**
- what was a new result: **lines 463-491 for SCU, 511-535 for OFU, whole section 4.4 and lines 694-715 in section 5.4 for NCU, whole section 4.5 for MKU**.

Last, the **Conclusion** was almost completely rewritten and shorten to really highlight the new results of this study. We also avoided using terms as "background circulation" and "mesoscale structures".

Section 4.3: The authors proposed 4 situations that help/prevent NCU occurs.

(1) Strong southward alongshore current prevents NCU.

(2) Strong northward alongshore current weakens NCU.

(3) Secondary dipole and the relating secondary offshore jet strengthens NCU.

(4) Weaken dipole structure and offshore jet strengthen NCU.

These situations seem to conflict with each other and no further quantitative analyses are employed to prove their hypothesis.

This comment of the reviewer shows that the previous version of manuscript regarding NCU was not clear enough. We tried to explain this better here:

1) The NCU is inhibited when alongshore currents, either southward or northward, prevail over BoxMK. Southward alongshore currents prevail during summers of strong wind over the SVU region, when the dipole and

eastward jet, hence positive vorticity $\zeta_{+,OF}$, are highly marked, inducing strong OFU and SCU (see summers 2009, 2012 and 2018, Figures 11,12,13 of the revised document). These southward currents are associated with the western part of the northern cyclonic gyre and a divergent circulation, hence with a coastward component and a coastal downwelling which inhibits the NCU. Northward alongshore currents prevail during years of weak or average wind over the region (summers 2010, 2013, 2017, Figures 11,12,13). During those years, offshore circulation (AC/C dipole and eastward jet) is average (2017), weak (2013) or even absent (2010), resulting in weak average Ekman transport and pumping, hence in weak SCU and OFU. The weakness of the offshore circulation allows the development of an alongshore northward current all along the Vietnamese coast (Figure 12), which also inhibits the NCU. Southward or northward longshore currents over BoxNC therefore result from two opposite situations in terms of wind and offshore circulation, but induces both NCU inhibition.

2) The NCU is enhanced when offshore oriented circulation prevails over BoxMK. Offshore oriented circulation can result first from the development of a secondary dipole north of the usual dipole structure (see for summers 2011, 2014 and 2015 the alternation of negative and positive vorticity between 12°N and 16°N, Figure 12). This secondary dipole is associated with a second coastal area of convergence over BoxNC, hence a secondary eastward jet that induces the strong NCU. This situation is not related to the intensity of wind intensity or summer offshore circulation: it occurs both for summers of slightly stronger (2011 and 2014, Figure 13) or weaker than average (2015) wind and strong (2014, Figure 12) or weak (2011, 2015) offshore circulation. Offshore oriented circulation can also develop when a weaker but wider than average eastward jet prevails over a large part of the coastal region, including BoxNC (see summer 2016, Figure 12). This results in the offshore advection of cold water all along the coast hence in the development of a stronger than average NCU. NCU is therefore favored by the development of offshore oriented currents along the coast that result from a favorable spatial organization of submesoscale to mesoscale dynamics.

We therefore mainly show that the development of NCU is inhibited or favored depending on the circulation that prevails over BoxNC, independently of the large scale forcing wind and offshore circulation.

→ Following this comment, we completely rewrote Section 4.4 in the revised version of the manuscript **(lines 545-569).** We moreover commented more into details the differences between conclusions of Ngo and Hsin (2021) and our conclusions regarding NCU : those differences could be related partly to the lower resolution of satellite dataset used by *Ngo and Hsin (2021*) but also to the strong impact of OIV over BoxNC, related to the strong influence of submesoscale to mesoscale dynamics in the functioning of NCU **(Sections 5.3 and 5.4, lines 666-675 and 693-714).**

c) Figure 4i-4l, The authors compared the basin-scale SCS circulation based on the sea level anomaly field, which only expresses the anomalous flow field. This is not proper for describing basin-wide circulation, because it should include both mean flow and anomalous flow. Besides, the authors claimed an eastward jet appears in the modelled and satellite-derived anomalous flow field (L239-243); however, I cannot see that!

We computed and plotted the field of absolute sea surface height (SSH) and associated total geostrophic current for the model and for data (AVISO) in see figure G (1st row) below. The 2nd row (former Figure 4) shows their anomaly. The patterns of currents and of their anomalies are actually quite similar. On the total geostrophic current, the AC/C dipole and eastward jet is actually better visible, and highlighted by grey arrows.

→ Following this comment, we showed SSH and associated total geostrophic, rather than their anomaly, in Figure 2k-l of the revised manuscript.

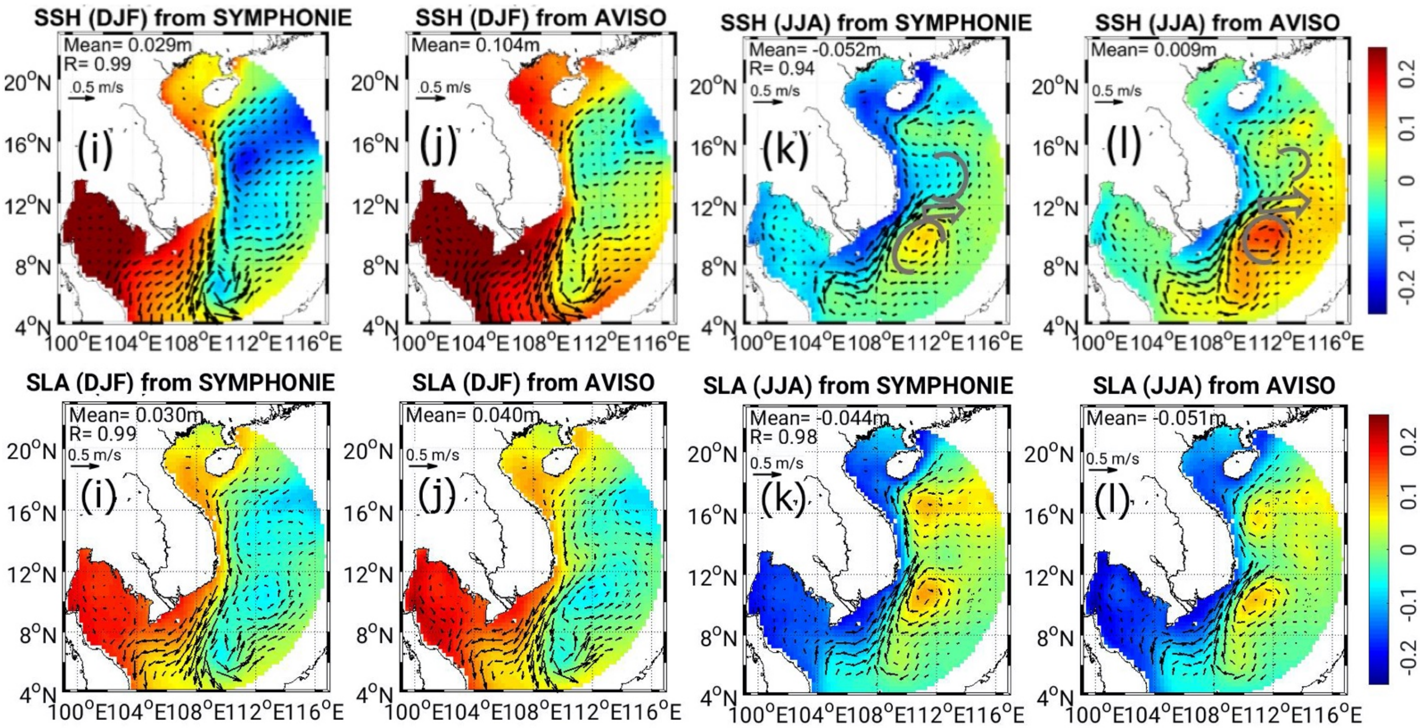

Figure G: Spatial distribution of simulated and observed winter (DJF) and summer (JJA) climatological averages of SSH (i,j,k,l, m) and total surface geostrophic current (m.s^{-1}) (1st line) and of their anomaly (2nd line), and spatial correlation coefficient R (here the p-value is always smaller than 0.01). Grey arrows on panels k,l highlight the summer AC/C dipole and eastward jet.

3. Conclusion:

Factor like wind stress curl has not been carried out in the analyses but still appear in the conclusion.

→ Following the comment of the other reviewer, the link between wind stress curl and wind stress, and circulation, is not discussed in the new **Section 4.1 Interannual variability of wind and offshore summer circulation (p14)**

Minor Comments:

L18 "mesoscale ocean dynamics" should be more concise or direct to the point.

→ This was replaced by "mesoscale to regional ocean circulation." **(line 19)**

L63 "influences"

→ This was corrected**, line 64**

L73 "varies"

→ This was corrected**, line 83**

L158 The mean bar notation should be put overline

→ This was corrected**, line 282**

L197 "The fourth area"

→ This was corrected**, line 220**

L226 For accuracy, comparison between the spatial-mean simulated and observed SST, SSS and SLA could be done over a smaller area such as the VNU rather than the whole VNC domain.

→ Indeed, our study focuses on the SVU. Following this comment, we added **in Figure 7** of the revised manuscript the times series of the same variables but averaged over the SVU domain (104-116°E; 7-16°N). **Figure 7 of the revised manuscript** shows that (except for SLA for which seasonal variations over the smaller SVU domain are weak) both VNC and SVU domains show very similar behaviors in terms of seasonal cycles and interannual variations of SST, SSS and SLA, and performances are very slightly better on the SVU region. We commented the updated figure in parts 3.2.1 and 3.2.2 of the revised manuscript (see changes highlighted in green at the beginning of each paragraph**, lines 288-291, 310-313321-323, 336, 343-344, 349-350**).

L254-257 "Though SYMPHONIE is overall ... Woo et al. (2020)". Quantitative assessment of the overestimating of the surface cooling in the southern Vietnam coasts is missing, which is important for evaluating SST in the upwelling region. The reader is left wondering, the SST overestimating is caused by SYMPHONIE output or OSTIA? It further raises the question that if upwelling occurs in BoxMK in reality.

This question is related to the question of spatial observation of surface cooling that occurs in small coastal areas (see our answer to the question of upwelling over BoxMK above) : the scarcity of observations in summer over those coastal areas, due in particular to a high cloud cover, and the smoothing done to produce analysis data like OSTIA, explains a large part of the difference between SYMPHONIE and OSTIA. Note however that other factors could be involved that would explain an overestimation of surface cooling in the model : biases in atmospheric fluxes, overestimation of vertical mixing in SYMPHONIE due to the numerical design (schemes of advection and diffusion, vertical coordinates …) (though the comparison with in-situ temperature and salinity profiles shows the good performance of the model in the representation of water masses characteristics, section 3.2). Those questions are actually important topics of research in our group.

→ A paragraph about this was added in the revised manuscript (lines 301-309)

L233 L245, L261, L270, L275, L280 Inconsistencies in describing NRMSE, sometimes use "%", sometimes use decimal.

→ We provided all NRMSE values in decimal everywhere in the paper

L235, globally?

→ we removed this word

L292 - L299 Long description

→ We shorten this (**lines 359-3656)** removing in particular the long water masses names whose definition is provided in the caption of **Figure 8** of the revised manuscript.

L307 Figure SM1 is not found in the manuscript.

→ We provided this figure in the document containing all the figures, after Figure 17

L341 "... the lowest of the 4 boxes...". The lowest of what?

We meant the weakest upwelling interannual variability of the 4 boxes (lowest value of CV)

→ Our sentence was indeed not clear, we replaced it by “The inter-annual variability of SVU is significant, although it is the weakest of the 4 boxes” (**line 452)**

L391 Definition of "OIV" haven't been mentioned.

OIV (ocean intrinsic variability) was actually defined in the introduction when citing the work of Da et al. 2019 (**line 97**), but it was quite far from this occurrence of this acronym.

→ We recalled the definition **on line 664**

L357-L358 Values of UI need to be checked again.

→ We carefully checked our values of UIy for boxSC using a unique and constant Tref fpr all boxes (figure 16b): it is ~0.75°C in 2009, ~1.35°C in 2011, ~0.95°C in 2012, ~1.50°C in 2018, i.e. the same as obtained before.

L356-L365 The authors compare the differences between 2009 and 2012 of the daily/monthly wind stress and daily upwelling index and conclude that the daily to intra-seasonal variability of wind forcing modulate the SCU interannual variability. However, this analysis does not make sense to me because they are the different time scales. Similar comments for the OU and NCU.

Indeed, interannual variability of upwelling intensity daily variability to intraseasonal variability) of wind stress and upwelling are two different time scales. Our goal here was to show that the second (intraseasonal variability variability) influences the first (interannual variability), and how: depending on the daily chronology of wind forcing, the summer average of upwelling intensity, and thus its interannual variability, varies. For SCU, regular wind peaks all along the JJAS period result in a stronger summer average of upwelling intensity than intermittent peaks. For OFU, a stronger wind stress during the July-August period results in a stronger upwelling intensity. To better quantify the role of intraseasonal variability of wind stress in the summer average of upwelling and its interannual variability, we performed an additional simulation from June to September 2018 (the summer that shows the strongest wind stress and upwelling over BoxSC, BoxOF and BoxMK). We prescribed during the whole summer period a temporally constant (but spatially varying) wind stress to the model: for each point of the model. This constant was computed as the JJAS average of the 2018 daily wind stress at this point. Initial conditions for this simulation were taken as the conditions of June 1st, 2018 of the 2009-2018 simulation. The average summer wind in this simulation and the average 2018 summer wind in the 2009-2018 simulation are therefore equal by construction, but wind in the sensitivity simulation does not show any daily to intraseasonal variability. In this sensitivity simulation, the surface cooling is much weaker than in the 2009-2018 simulation, and no upwelling develops on any of the boxes during the whole summer. This result quantitatively highlights the fundamental role of wind intraseasonal variability in the development of upwelling and in its summer average intensity.

→ Following this comment, we more clearly wrote the sentences about the link between intraseasonal variability of wind and summer average of upwelling intensity and its interannual variability in the revised version of the manuscript (**lines 466, 473-475, 520, 526**). We also added a section in the discussion in the revised manuscript where we discuss this point, to present the sensitivity simulation and to call for sensitivity simulations (**section 5.2 Role of intraseasonal variability of atmospheric forcing, p19** and **lines 785-787** in the conclusion).

L372, L373 "is (not) related to" should be " (does not) relate(s) to"

→ We replaced “is (not) related to” by “results from “ or “does not results from”

L393 Vorticity calculation has not been described. What kind of vorticity? How do the authors define the surface current? Which depth layer of velocity do they use for the calculating?

Vorticity ζ is computed as the vertical component of surface current rotational: $\zeta = dv_{surf} / dx - du_{surf} / dy$. The surface current is taken as the current of the first layer of the model, whose depth varies from ~1.00m over most of the domain to ~0.7 m in shallow areas very close to the coast (less than ~20 km).

→ This was detailed in the revised manuscript (**lines 413-416)**

L503-509 “This current constitutes …the stable position of MKU”. This inference needs more evidences.

→ This part was revised to be less affirmative (**lines 589-595 and 603-605)**

Figures:

Figure1: VNC configuration should be described in detail, especially the coastal region, rather than locations of 4 upwelling areas, which are displayed again in Figure 2c.

→ we added a zoom in **Figure 1c** to show the details of the grid and bathymetry over the SVU region

Figures 3 and 4: There is an inconsistency that exists between the order of figures and the text's description, which makes the reader hard to follow.

Indeed, in the figure, the order is SST, SSS, SLA, and in the previous version, in the text, we commented successively SLA, SST and SSS, which made it difficult to follow.

→ In the revised manuscript, in **sections 3.2.1 and 3.2.2**, we now comment successively SST, SST and SLA, i.e. using the same order as for **Figures 2 and 7**.

Figure 5: "... ARGO (a, black dots and purple for mean), GLIDER (b, black dots and cyan for mean), IO-18 (c, black dots and green for mean) observations and from SYMPHONIE (yellow dots and red for mean) colocalized outputs..." should be "... ARGO (a, black dots and purple line), GLIDER (b, black dots and cyan line), IO-18 (c, black dots and green line) observations and from SYMPHONIE (yellow dots and red line) colocalized outputs...". However, the caption should be better clarified.

→ We have reworded the legend to make it clearer (**Caption of Figure 8)**

Figure 7: Legendaries of x and y axes are overlaid (year 2018)

→ This was corrected (**now Figure 13)**

Figure 8: Purple contours in a,b,c,d,i,j,k,l,q,r and blue contours in e,f,g,h,m,n,o,p,s,t have no explanation.

The pink contours show the area of positive wind stress curl. The blue contours corresponds to the contours of UIy=0.01°C

→ This was added in the caption of **Figure 12,** and wind stress and wind stress curl is shown **in Figure 11.**

Figure 9 and Figure 10: The ranges of y-axis should be fixed with the presented data

→ A hurricane hit the SVU region at the end of 2009 (see figure H below extracted from the NOAA website). Wind and wind stress during this event were therefore exceptionally strong. Adapting the y-range would make the rest of the wind stress time series difficult to read, and the storm occurred at the very end of the simulation (1 value of the time series), it therefore does not have a strong impact on the upwelling on the summer average. We therefore deliberately keep the y-axis unchanged, but mentioned this in the **caption of Figures 14 and 15** of the revised mauscript. Note however that for BoxOF this storm, presumably due to the very strong positive wind stress curl, induced a strong upwelling during the last day of JJAS. This will be interesting to be investigated in more detailed studies.

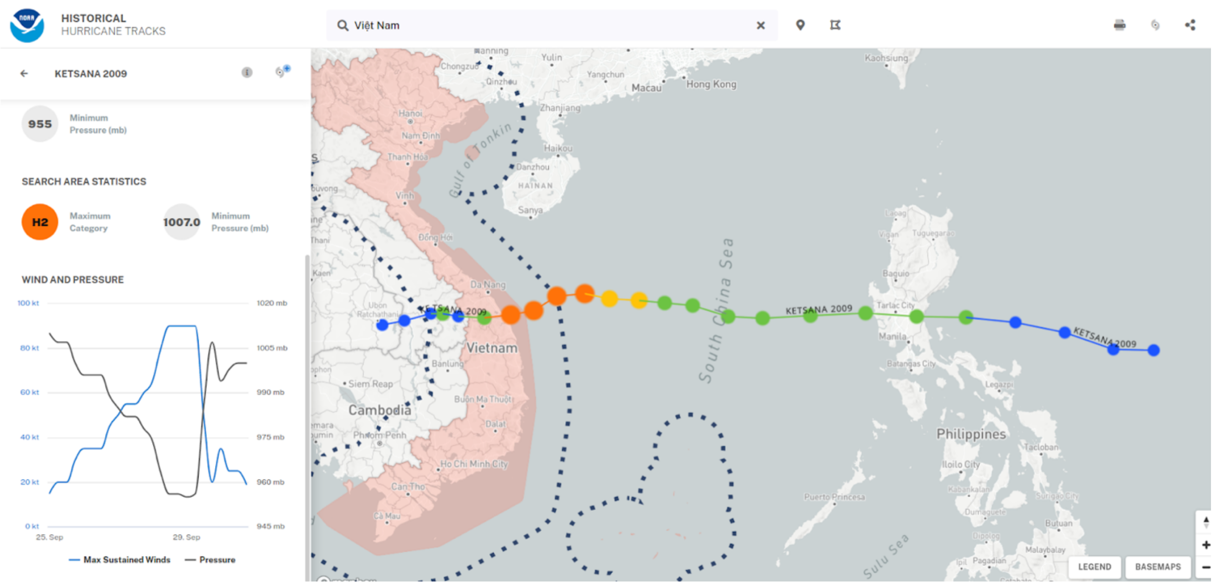

Figure H : Copy of NOAA website for the KETSANA hurricane that hit Vietnam end of September 2009

References :

UK Met Office. 2005. OSTIA L4 SST Analysis. Ver. 1.0. PO.DAAC, CA, USA. Dataset accessed [YYYY-MM-DD] at https://doi.org/10.5067/GHOST-4FK01

Da, N. D., Herrmann, M., Morrow, R., Niño, F., Huan, N. M., and Trinh, N. Q. (2019). Contributions of wind, ocean intrinsic variability, and ENSO to the interannual variability of the south vietnam upwelling: A modeling study. Journal of Geophysical Research: Oceans, 124(9), 6545–6574. https://doi.org/10.1029/2018jc014647

M. Herrmann, S. Somot, F. Sevault, C. Estournel and M. Déqué (2008). Modeling deep convection in the Northwestern Mediterranean Sea using an eddy-permitting and an eddy-resolving model: case study of winter 1986-87. J. Geophys. Res. 113, C04011, http://dx.doi.org/10.1029/2006JC003991

Li, Y., Han, W., Wilkin, J. L., Zhang, W. G., Arango, H., Zavala-Garay, J., Levin, J., and Castruccio, F. S. (2014). Interannual variability of the surface summertime eastward jet in the South China Sea. Journal of Geophysical Research: Oceans, 119(10), 7205–7228. https://doi.org/10.1002/2014jc010206

Ngo, M., and Hsin, Y. (2021). Impacts of wind and current on the interannual variation of the summertime upwelling off southern Vietnam in the South China Sea. Journal of Geophysical Research: Oceans, 126(6). https://doi.org/10.1029/2020jc016892

To Duy Thai, 2022, Interannual to intraseasonal variability of the South Vietnam Upwelling. Role of multi-scale wind and ocean dynamics. A. high-resolution modeling study. PhD Thesis. Université de Toulouse 3, Toulouse, France.