Dear John M. Huthnance,

We appreciate your nice help to our paper. We have addressed all the comments accordingly. In order to enhance the readability of our manuscript, Dr. Yang Lei and Dr. Yao Jinglong has discussed with us and revised the manuscript for nearly six times. We add Dr. Yang Lei (State Key Laboratory of Tropical Oceanography (LTO), South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, China, leiyang@scsio.ac.cn) and Dr. Yao Jinglong (State Key Laboratory of Tropical Oceanography (LTO), South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, China, yaojl@scsio.ac.cn) as our coauthors.

Please find our responses and the revised manuscript in the attached files.

Thank you again.

Referee #1

We thank C. Li for his careful comment of our paper submitted to Ocean Science. We appreciate the thoughtful and constructive feedback on the paper, which has helped to significantly improve the manuscript. We have addressed all concerns in the revised manuscript, as documented in our point-by-point responses.

General Comment

The authors only use 120 day data in 2010 to analyze the near-inertial variation of SCSMOC (Figure 2), which seasons are these data from? But with mooring data, it is 120-day data since 1 April 2006. Can your model reproduce the near-inertial variations as you mooring data with the same time period? Do these phenomena also exist in other seasons and any other years? Is there any seasonality of the near-inertial variations? I suggest the authors also include some analysis from other years, to demonstrate that the near-inertial variation triggered by Kuroshio intrusion is a common feature of SCSMOC, not a specific phenomenon in your selected period.

Reply: Thank you for your careful review. We use 120 day model output since 00:00, 1 January, 2010 in Figure 2. As the reviewer suggested, we use the mooring data to validate the model output based on the spectral analysis, as shown in Figure A1.Because of no tide forcing in the model, the tide effects have been removed in the mooring data. Figure A1 shows that the model can reproduce the near-inertial variations as the mooring data with the same time period well. We also use the model data of four typical month (January, April, July and October) in three years(2000,2006,2010) to show whether near-inertial variations of the SCSMOC also exist in other seasons and any other years, as shown in Figure A2(2000), Figure A3(2006), Figure A4(2010).Our results show that these near-inertial variations of the SCSMOC exists in other seasons and other years. The near-inertial variations of the SCSMOC has a strong seasonality as shown in Figure A5.The analysis of other months or years cannot change our conclusion significantly, so we just use the 2010 data to depict the near-inertial variations of the SCSMOC.

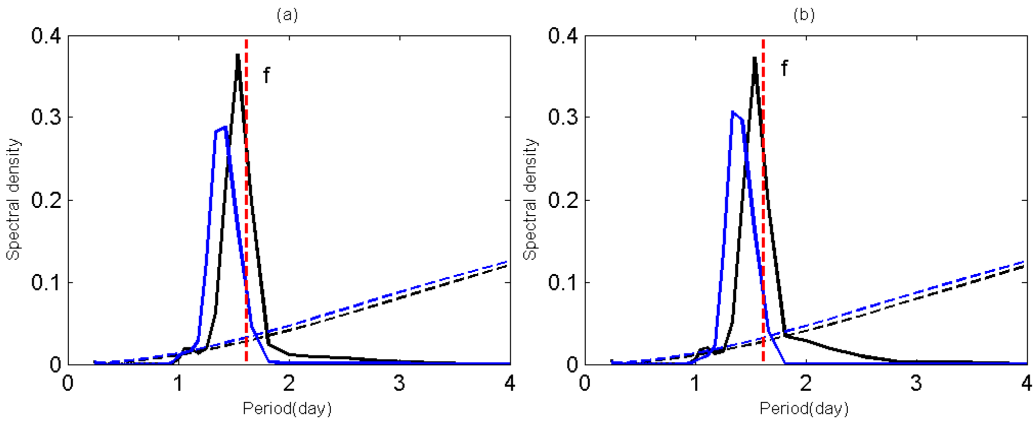

Figure A1 The power spectrum of zonal velocity (a) and meridional velocity (b) derived from the mooring (black line) and GLBu0.08 (blue line). The dashed black and blue line shows 95% confidence levels. The dashed red line represents the local inertial period. The tide effects have been removed in the mooring data.

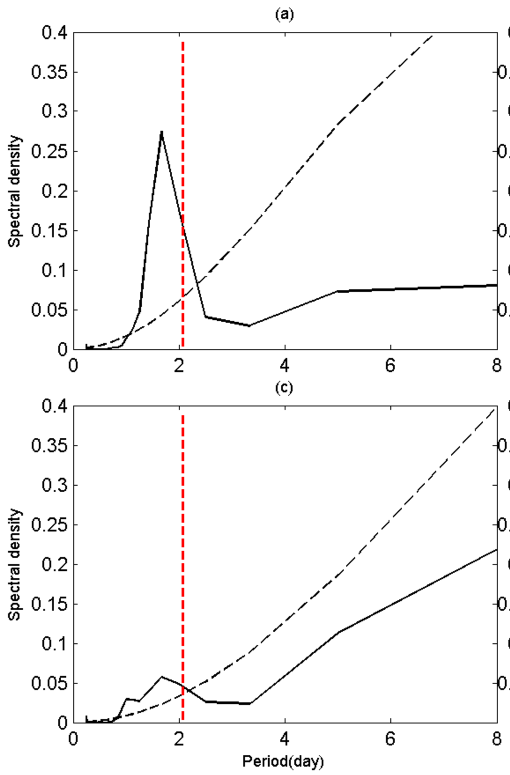

Figure A2 The power spectrum of SCSMOC at 1500m, 14°N in (a) January,(b) April, (c) July and (d) October in 2000. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

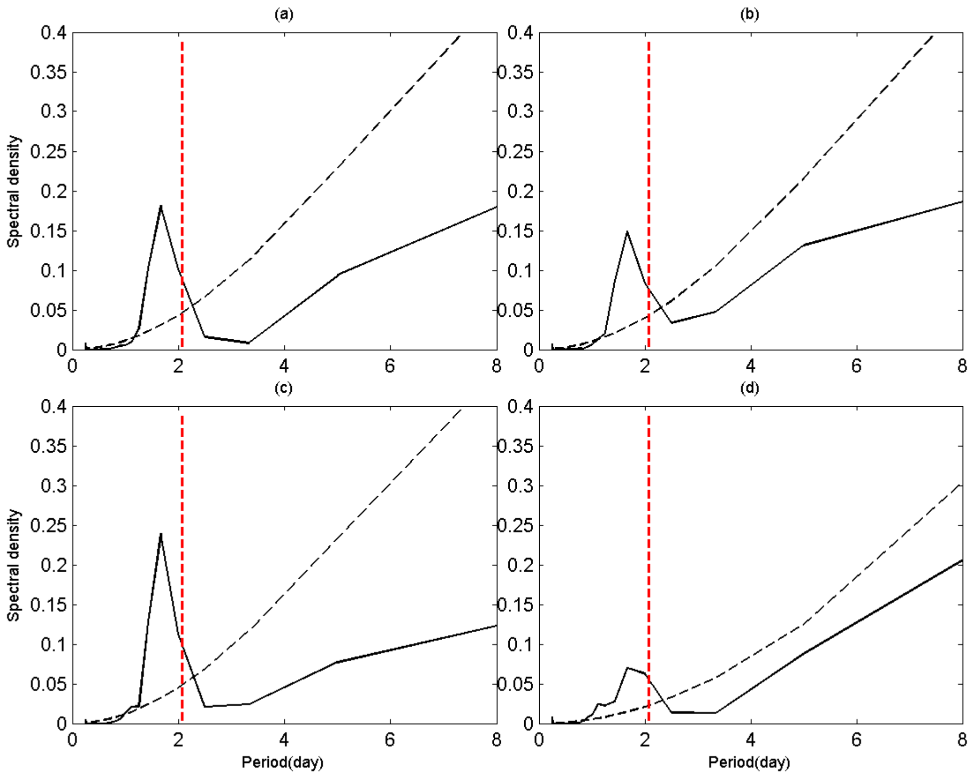

Figure A3 The power spectrum of SCSMOC at 1500m, 14°N in (a) January,(b) April, (c) July and

(d) October in 2006. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

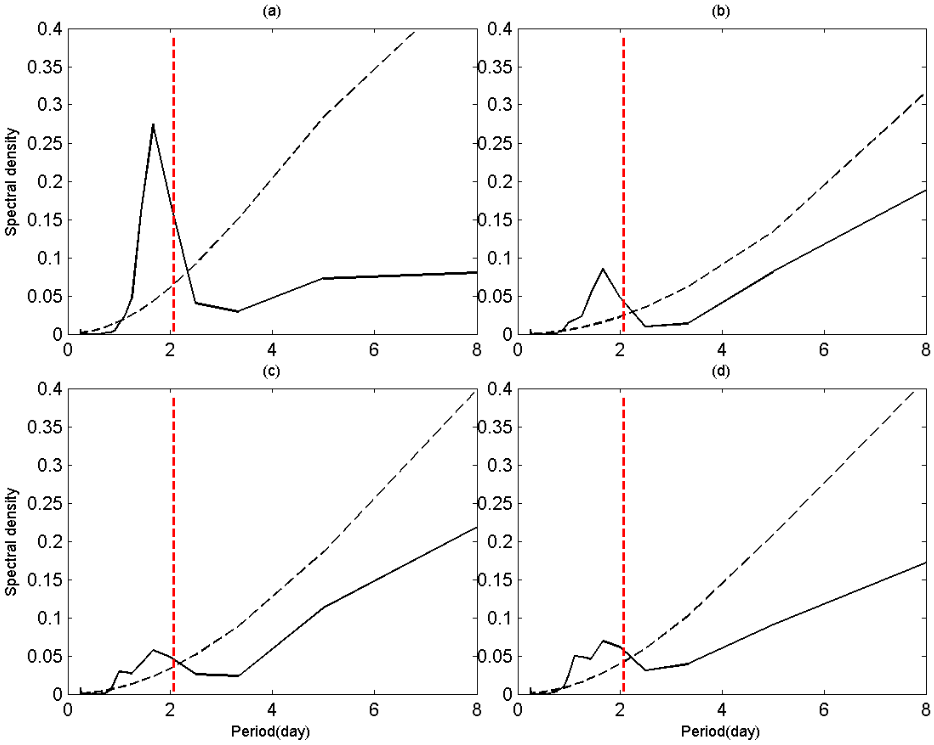

Figure A4 The power spectrum of SCSMOC at 1500m, 14^{o}N in (a) January,(b) April, (c) July and (d) October in 2010. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

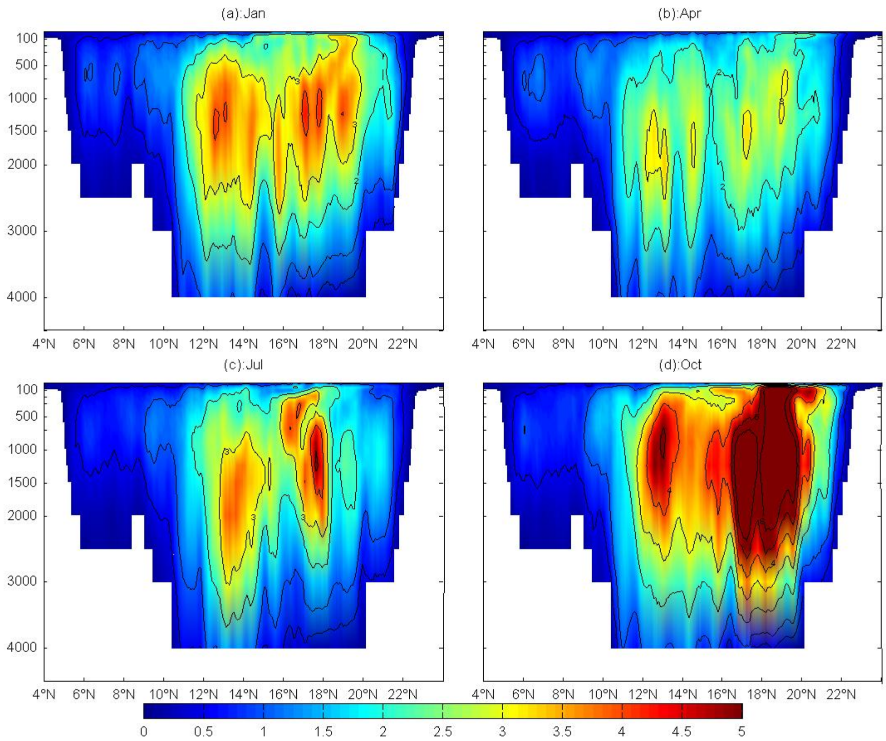

Figure A5 The standard deviations of the SCSMOC during (a) January,(b) April, (c) July and (d) October in 2010.

Comments

1. I suggest the author to revise the title of your paper, because the near-inertial variability of SCS MOC can also be observed in mooring data, which is shown in Fig. 7. And I am not sure whether is ok to call it near-inertial variability, which is a noise phenomena. My suggestion is "On the near-inertial variations of South China Sea meridional overturning circulation".

Reply: Thank you for pointing out this poor wording. The title will be "On the near-inertial variations of meridional overturning circulation in the South China Sea".

2. Line 2-3: "The near-inertial variability of … has been analyzed based on …" should be "We analyze the near-inertial variability of …". "has been analyzed" sounds like the work has been done by previous studies.

Reply: We are sorry for this poor wording. We have updated this sentence as the reviewer suggested.

3. The introduction does not service very well. I cannot directly see what is you research questions? What is new? And why is important? I suggest the authors have a topic paragraph at the begging of the introduction.

Reply: The SCSMOC represents the connection between the deep circulation and the upper circulation in SCS. The Luzon Strait transport plays an important role in the SCSMOC, so we first depict the Luzon Strait transport in the first paragraph, and then we just describe the structure of the climatological SCSMOC. Finally, we just state the variability of the SCSMOC from the decadal scale to seasonal scale, but there is no study for the more high-frequency variability of the SCSMOC. Our study is inspired by the near-inertial variations of AMOC because near-inertial internal waves have been believed to be an important energy source for the diapycnal mixing in the ocean required to maintain the meridional overturning circulation (MOC) (Munk and Wunsch 1998; Blaker et al., 2012; Sévellec et al., 2013). We are just sorry for the sketchy statement in fourth paragraph in our introduction. And the fourth paragraph in our introduction has been revised.

Ref:

Munk, W., and C. Wunsch, 1998: Abyssal recipes II, Energetics of tidal and wind mixing. Deep Sea Res. I, 45, 1977–2010.

Blaker, A. T., Hirschi, J. J. M., Sinha, B., de Cuevas, B., Alderson, S., Coward, A., and Madec, G.: Large near-inertial oscillations of the Atlantic meridional overturning circulation, Ocean Model., 42, 50–56, 2012.

Sévellec, F., Hirschi, J. J. M., and Blaker, A. T.: On the Near-Inertial Resonance of the Atlantic Meridional Overturning Circulation, J. Phys. Oceanogr., 43, 2661–2672, 2013.

4. Line 22-26: I do not agree with the authors that SCS circulation in reality as described in the introduction is consistent with a highly simplified theory. They are different in many details. Stommel-Arons theory from 1960s has been developed to explain Atlantic MOC and global MOC, it is a basic theory for the global deep ocean circulation, and the theory for the deep circulation has been further discussed by Marotzke and Scott (1999) and Munk and Wunsch (1998). I am not sure whether you can really use Stommel-Arons theory to explain SCS circulation which is externally

mainly driven by Kuroshio intrusion and Asian monsoon system. The vertical structural of SCS MOC and Atlantic MOC are also different. The authors must be careful for your statements, which should be supported by our analysis or reference. ******Section 3. Characteristics of the near-inertial variability of the SCSMOC*************

Reply: We have read the analysis or references suggested by the reviewer carefully. The statement of SCS circulation related to the Stommel-Arons theory is mostly referred to Yuan,D,2002. He just related the SCS circulation to Luzon Strait transport through the vorticity balance between the vortex stretching and the meridional change of the planetary vorticity. Based on the simulation result, he just hypothesized that the simulated three-layer SCS circulation is consistent with the Stommel-Arons theory. We have checked the statement using recent studies. Actually, the deep cyclonic SCS circulation can be explained by the Stommel-Arons theory (Qu et al., 2006; Wang et al., 2009), but the application of the classic theory in the upper-layer SCS circulation is not so accurate as the reviewer suggested, although there are some scholars like Yuan to support this statement.

The more accurate statement of the SCS circulation should be based on the Yang-Price potential vorticity constraint (Yang, J. and J. F. Price, 2000; Yang, J. and J. F. Price, 2007).For the deep and intermediate SCS circulation, the steady Yang-Price PV constraint is

$$\frac{\overline{Q}_L f_L}{H_L} = -\lambda \oint_c (\overline{u}_h \cdot l) ds \quad (1)$$

Where $\overline{Q}_L$ is the deep or intermediate Luzon Strait transport, f_L is mean latitude of the deep or intermediate Luzon Strait, and H_L is the deep or intermediate layer of the Luzon Strait. For the semi-enclosed SCS deep basin, when there is a positive PV transport into the basin by the deepwater overflow through the Luzon Strait, the SCS deep circulation becomes cyclonic so that friction can generate a flux of negative PV to satisfy the integral balance. For the intermediate SCS basin, a negative PV transport into the basin by the intermediate Luzon Strait transport, so the SCS intermediate circulation becomes anti-cyclonic (Lan et al,2013&2015).

For the upper-layer SCS circulation, the steady Yang-Price PV constraint is,

$$\frac{\overline{Q}_L f_L}{H_L} - \iint \frac{\nabla \times \vec{\tau}}{\rho_0 h} dxdy = -\lambda \oint_c (\overline{u}_h \cdot l) ds \quad (2)$$

Where $\vec{\tau}$ is wind stress vector and h is the depth of the upper-layer SCS. For the climatological upper-layer SCS, both the Kuroshio intrusion through the Luzon Strait and the wind stress curl play a role in the dynamic of the upper-layer SCS circulation(Xu et al,2014).

Based on the above statement, the statement in the manuscript will revised using Yang-Price PV constraint which is more applicable in the three-layer SCS circulation.

Ref:

Yuan, D.: A numerical study of the South China Sea deep circulation and its relation to the Luzon Strait transport, Acta Oceanol. Sin., 21, 187–202, 2002.

Yang, J., and J. F. Price, 2000: Water mass formation and potential vorticity balance in an abyssal ocean circulation model. J. Mar.Res., 58, 789–808, doi:10.1357/002224000321358918.

Yang, J., and J. F. Price, 2007: Potential vorticity constraint on the flow between two basins. J. Phys. Oceanogr., 37, 2251–2266,doi:10.1175/JPO3116.1.
Wang, G., Xie, S. P., Qu, T., and Huang, R. X.: Deep South China Sea circulation, Geophys. Res. Lett., 38, L05601, doi:10.1029/2010GL046626,2011.
Qu, T., Girton, J. B., and Whitehead, J. A.: Deepwater overflow through Luzon strait, J. Geophys. Res.-Oceans, 111, C01002, doi:10.1029/2005JC003139, 2006.
Lan, J., Zhang, N., and Wang, Y.: On the dynamics of the South China Sea deep circulation, J. Geophys. Res.-Oceans, 118, 1206–1210, 2013.
Lan, J., Wang, Y., Cui, F., and Zhang, N.: Seasonal variation in the South China Sea deep circulation, J. Geophys. Res.-Oceans, 120, 1682–1690, 2015.
Xu, F. H. and Oey, L. Y.: State analysis using the Local Ensemble Transform Kalman Filter (LETKF) and the three-layer circulation structure of the Luzon Strait and the South China Sea, Ocean. Dynam., 64, 905–923, 2014.

5. Line 10: Why do you define the SCSMOC index as the streamfunction at a depth of 1500m at 14^{o}N? How good is your index in representing SCSMOC variations? And will other index of SCS MOC change the conclusion of the present study?

Reply: We use SCSMOC index as the stream function at a depth of 1500m at 14^{o}N, because this point is far away from the Luzon Strait. We have checked the SCSMOC index in the different latitude and depth, as shown in Figure A6 and A7. Actually, the analysis of the index of the SCSMOC in other latitude and depth is nearly the same to the stream function at a depth of 1500m at 14^{o}N for the near-inertial variations of SCSMOC, and cannot change our conclusion of the present study.

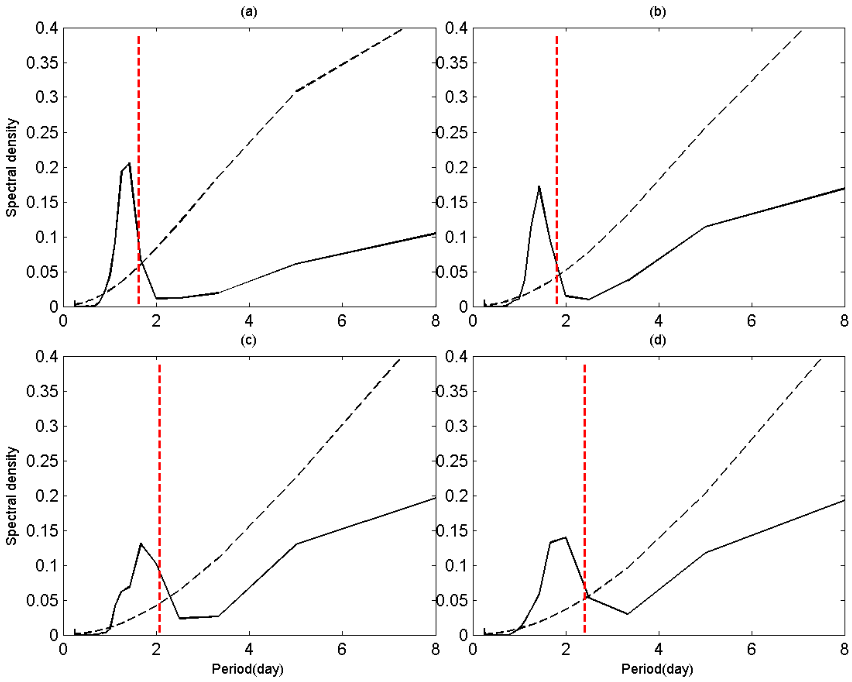

Figure A6 The power spectrum of SCSMOC at 1500m, **18^{o}N**(a),1500m, **16^{o}N**(b),1500m, **14^{o}N**(c) ,and 1500m, **12^{o}N**(d) during January in 2010. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

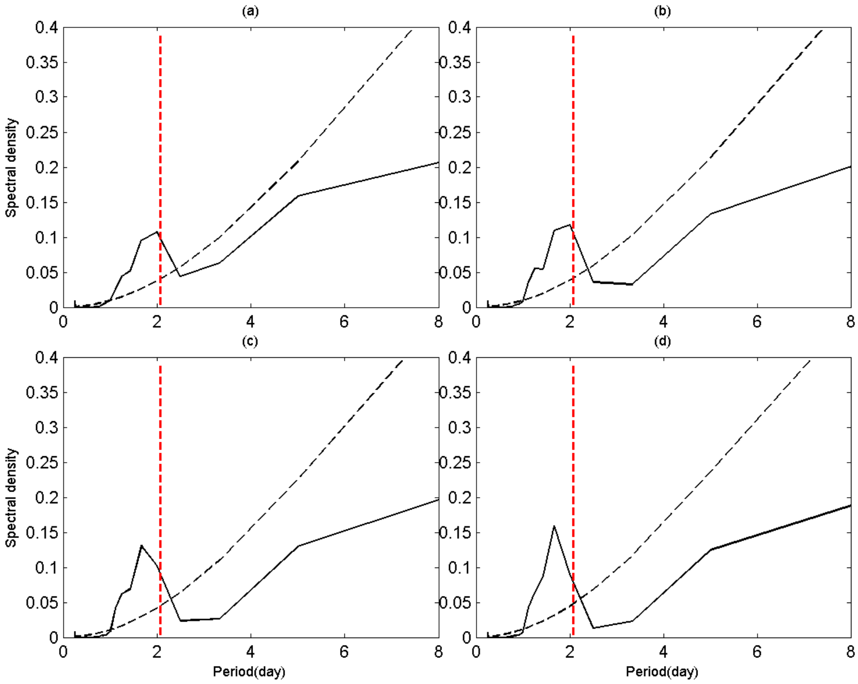

Figure A7 The power spectrum of SCSMOC at **500m**,14^{o}N(a),**1000m**,14^{o}N(b),**1500m**, 14^{o}N(c) ,and **2000m**, 14^{o}N(d) during January in 2010. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

6. Line 20-24: "The pattern of the near-inertial variability of SCSMOC is very similar to the near-inertial variability of the Pacific Ocean or Atlantic. And the period corresponding to the power peak of the AMOC is mostly at near inertial periods (Komori et al.,2008), which indicates that the near-inertial signal of the SCSMOC is not unique in nature."How can you make such a conclusion? The amplitude of the standard deviations are different, and the location of the maximum are different, and SCS MOC has two maximum center of the standard deviations, but Atlantic MOC only has one. As I said, your statements and conclusions must be drawn with evidence. Every phenomenon can be unique in nature by itself.

Reply: We are sorry for the sketchy statement. We just deleted the sentence of "which indicates that the near-inertial signal of the SCSMOC is not unique in nature". For clarity, we have changed the sentence of "And the period corresponding to the power peak of the AMOC is mostly at near inertial periods (Komori et al., 2008), which indicates that the near-inertial signal of the SCSMOC is not unique in nature." into the statement of "The imprint of NIGWs in AMOC is also stacked with regularly alternating positive and negative cells in the depth between 500 to 4000m and within the latitude between 10 and 40^{o}N (Komori et al., 2008;Blaker et al., 2012; Sévellec et al., 2013). The period corresponding to the power peak of AMOC is at super-inertial periods, which is similar to that of the SCSMOC."

Another difference is that the imprint of NIGWs on AMOC has been found mostly triggered by wintertime storm tracks in mid-latitude, then the near-inertial phase velocity is larger than that in SCS in low-latitude because of beta effect. There are more statements for this point in Sec.4.

7. Your analysis of mooring data (Fig. 7), which is shown in this section, should appear earlier. Do you also find similar result of model reanalysis data if you also use 120 days data since 1 April

2006 as the Fig. 7? Maybe the authors can also evaluate the reanalysis data with the mooring data.

Reply: Strictly speaking, the observational system in full depth used as the validation of the simulated SCSMOC should consists of some typical latitude section cross the South China Sea like Rapid Climate Change–Meridional Overturning Circulation (RAPID-MOC) at 26.58°N in Atlantic. The previous study also suggest that the near-inertial AMOC variability is nearly invisible to AMOC-observing systems because of high-frequency observational sampling for near-inertial variation (Blaker et al., 2012 ;Sévellec,et al., 2013). Most of observational data focus on the 18°N section in the SCS, and the observational depth is just shallow then 2000m. Especially, We have no such observation system for the monitoring of the near-inertial variations of SCSMOC. We just put the analysis of the mooring data in the part of Discussion to show that there are also near-inertial variations in the deep SCS in observation. As the reviewer suggested, we use the mooring data in deep SCS to validate the model output, as shown in Figure A1.The power spectrum of the model output is similar to that of the observation data. And the model can produce the near-inertial variations in the deep SCS, which can validate the near-inertial variations of SCSMOC in our model data to a certain extent. We will replace Figure 7 with Figure A1 in the final manuscript.

Ref:

Blaker, A. T., Hirschi, J. J. M., Sinha, B., de Cuevas, B., Alderson, S., Coward, A., and Madec,G.: Large near-inertial oscillations of the Atlantic meridional overturning circulation, Ocean Model., 42, 50–56, 2012.

Sévellec, F., Hirschi, J. J. M., and Blaker, A. T.: On the Near-Inertial Resonance of the Atlantic Meridional Overturning Circulation, J. Phys. Oceanogr., 43, 2661–2672, 2013.

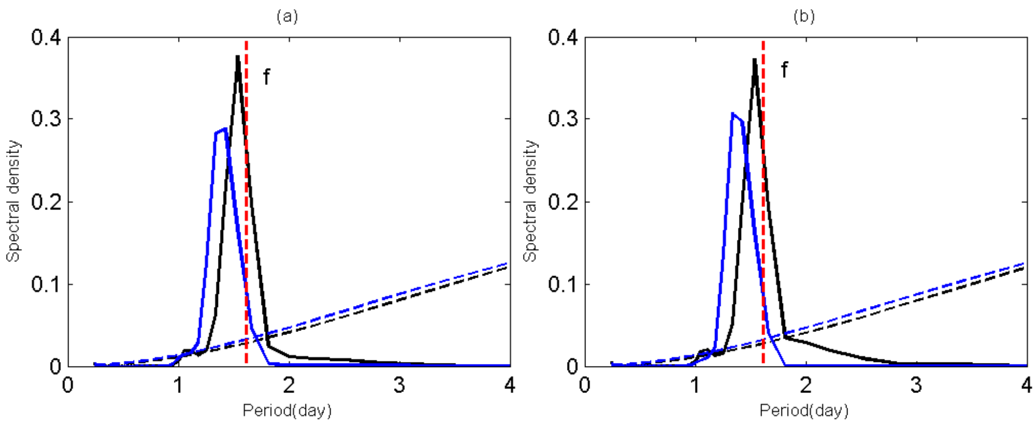

Figure A1 The power spectrum of zonal velocity (a) and meridional velocity (b) derived from the mooring (black line) and GLBu0.08 (blue line). The dashed black and blue line shows 95% confidence levels. The dashed red line represents the local inertial period. The tide effects have been removed in the mooring data.

8. Line 23: “However, the imprint of NIGWs on SCSMOC : : :”. “However” should be deleted. The imprint of NIGWs on MOC in Atlantic and SCS are related to high frequency winds.

Reply: We are sorry for this poor wording. “However” in Line 23 has been deleted.

9. “An average of about 7 TCs (tropical cyclones) pass through the Luzon Strait from the Northwest Pacific Ocean each year: : :, including strong wind-induced near-inertial energy input into the ocean (Fig. 8c), so TCs could also be drivers of the NIGWs near the Luzon Strait”. How many TCs pass SCS in July 2010? You may put the pathway of TCs in July 2010 on Fig. 8c. Otherwise, I do not know how can you draw a conclusion on the influence of TCs.

Reply: We are sorry for the sketchy statement. There were two TCs passing through the region near Luzon Strait on July 2010, as shown in the Figure A8.We have plotted the best track of TC derived from the Joint Typhoon Warning Center (JTWC) in Figure A8. We will replace Figure 8 with Figure A8 in the final manuscript.

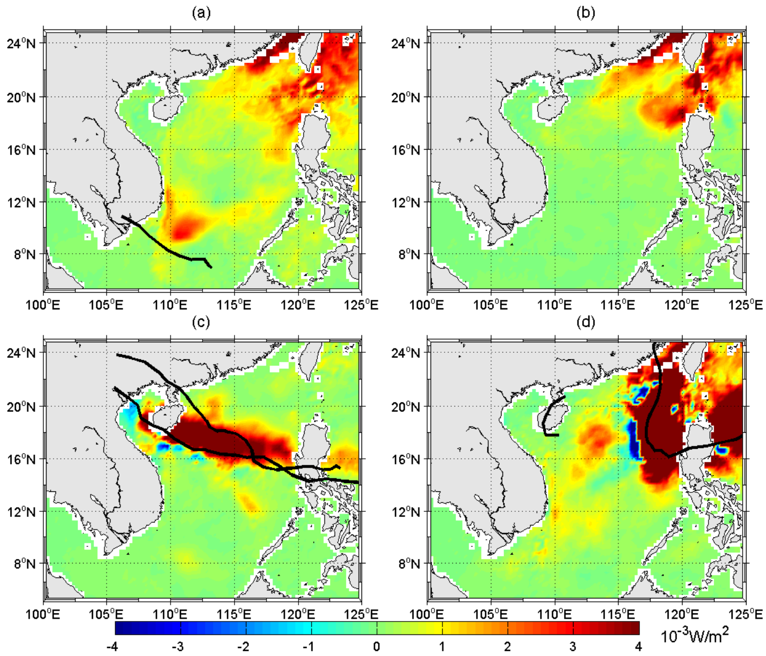

Figure A8 Spatial distribution of the monthly mean near-inertial energy input by wind in (a) January, (b) April, (c) July and (d) October in 2010.The black line is the best track of TC derived from the Joint Typhoon Warning Center (JTWC).

Anonymous Referee #2

We thank Referee #2 for his/her careful comment of our paper submitted to Ocean Science. We appreciate the thoughtful and constructive feedback on the paper, which has helped to significantly improve the manuscript. We have addressed all concerns in the revised manuscript, as documented in our point-by-point responses.

1. To my understanding, the authors conclude that the near-inertial signal of SCSMOC originates from the region near Luzon Strait but not Luzon Strait. The spatial patterns of near-inertial kinetic energy (Figure 9) show a clear discontinuity between North pacific and SCS at Luzon Strait (which could be pointed out in the discussion). So the statement of Line 8 in the abstract "originates from the Luzon Strait" is not accurate.

Reply: We are sorry for this poor wording. "originates from the Luzon Strait" will be revised as "originates from the region near the Luzon Strait".

2.Generally, both the Luzon strait and Kuroshio intrusion play important roles on SCSMOC. However, from the results of this study, the Luzon strait does not show a dominant effect on near-inertial wave on SCSMOC. I suggest that the authors start the introduction from SCSMOC instead of the Luzon strait.

Reply: The SCSMOC has a very complex structure, consisting of a stronger non-enclosed clockwise overturning circulation in the upper layer, a weaker counterclockwise overturning circulation in the intermediate layer, and a weaker clockwise overturning circulation in the deep layer, as shown in Shu et al (2014). The SCS cannot produce deep water by itself because it is in tropical region (Xie et al., 2013). The deep layer intrusion through the Luzon Strait has been considered as the only source for the SCS deep water (Qu et al., 2006). So the inflow through the Luzon Strait is the main source for the time-mean SCSMOC. We further study the near-inertial variability of SCSMOC and its possible mechanism. So we start the introduction just from Luzon Strait transport in our paper. Our study is not contraversal because we focus on shorter time-scale (several days) variability.

3. On Page 7, the sentence of "which indicates that the near-inertial signal of the SCSMOC is not unique in nature" needs to be deleted. It will be very beneficial for readers if the authors can discuss in detail the similarities and differences between near-inertial variability of SCSMOC and that of open ocean, such as Pacific or Atlantic.

Reply: We are sorry for the sketchy statement. We just deleted the sentence of "which indicates that the near-inertial signal of the SCSMOC is not unique in nature" as the reviewer suggested. Following the reviewer's suggestion, we have changed the sentence of "And the period corresponding to the power peak of the AMOC is mostly at near inertial periods (Komori et al., 2008), which indicates that the near-inertial signal of the SCSMOC is not unique in nature." into the statement of "The imprint of NIGWs in AMOC is also stacked with regularly alternating positive and negative cells in the depth between 500 to 4000m and within the latitude between 10 and 40^{o}N (Komori et al., 2008;Blaker et al., 2012; Sévellec et al., 2013). The period corresponding to the power peak of AMOC is at super-inertial periods, which is similar to that of the SCSMOC."

Another difference is that the imprint of NIGWs on AMOC has been found mostly triggered by wintertime storm tracks which is in mid-latitude, then the near-inertial phase velocity is larger than that in SCS. There are more statements for this point in Sec.4.

4. The authors conclude that "most of the signal propagates from 18N (the latitude of the southern tip of the Luzon Strait) ". Figure 8 shows strong near-inertial energy input north of 18N. Can the signal originate from north of 18N? It is hard to tell the location of 18N on figure 6.

Reply: We are sorry for this poor wording which is not consistent with Figure 8. In Section 2, the meridional overturning streamfunction in SCS could be defined as,

$$\psi(y,z,t)=\int_{-H}^{z}dz\int_{x_e}^{x_w}v(x,y,z,t)dx$$

This definition is frequently used in AMOC study. It represents the integrated meridional motions in the basin. When it is integrated from the east boundary to the west boundary in the basin, it is not accurately to see the exact origin of the near-inertial signal of the SCSMOC. For consistency with Figure 8, we just correct the sentence "most of the signal propagates from 18^{o}N (the latitude of the southern tip of the Luzon Strait) " into "most of the signal propagates from the region near Luzon Strait(where 18^{o}N is the latitude of the southern tip of the Luzon Strait in Fig. 6) ".

5. On Page 9, "An average of about 7 TCs pass through the Luzon Strait …". To make the conclusion robust, the authors have to add the number of tropic cyclones (TC) passing through the region near Luzon Strait on July 2010 in the discussion.

Reply: There were two TCs passing through the region near Luzon Strait on July 2010, as shown in the Figure B1.We have plotted the best track of TC derived from the Joint Typhoon Warning Center (JTWC) in Figure B1 and updated the statement in the revised manuscript. We will replace Figure 8 with Figure B1 in the final manuscript.

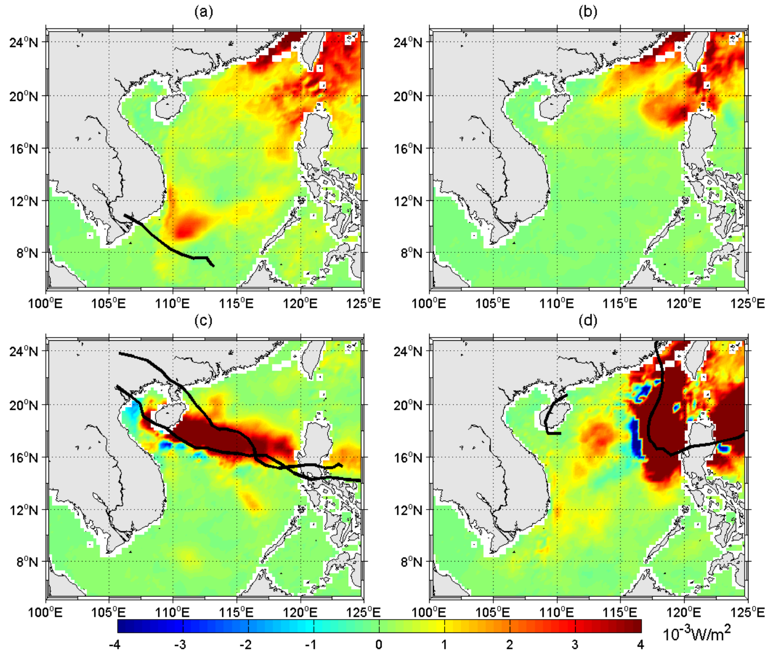

Figure B1 Spatial distribution of the monthly mean near-inertial energy input by wind in (a) January, (b) April, (c) July and (d) October in 2010.The black line is the best track of TC derived from the Joint Typhoon Warning Center (JTWC).

6. Please define the sub-inertial periods and super-inertial periods" on Page 6.
Reply: We just simply define sub-inertial period as the period corresponding to the power peak is larger than the local inertial period while super-inertial period as the period corresponding to the power peak is less than the local inertial period. As the reviewer suggested, we have updated the definition as the reviewer suggested.

7. On Page 3, at Line 2, a comma is expected between "...whole SCS basin in winter" and "and in summer...", to avoid unnecessary confusion.
Reply: We are sorry for this poor wording. We have updated this sentence as the reviewer suggested.

8 Page 7, Line 14-15. "These cells are not stretched in the meridional direction but in the vertical direction which means each cell consists of the strong upwelling branch and downwelling branch" can be revised as "These cells are stretched not in the meridional direction but in the vertical direction, which means each cell consists of both the strong upwelling branch and the downwelling branch".
Reply: We have updated this sentence as the reviewer suggested.

Short comment

We thank F. Nan for his careful comment of our paper submitted to Ocean Science. We appreciate the thoughtful and constructive feedback on the paper, which has helped to significantly improve the manuscript. We have addressed all concerns in the revised manuscript, as documented in our point-by-point responses.

1. In the Abstract (lines 9-11), the authors said that the near-inertial signal in the SCSMOC is triggered by variability near the Luzon Strait where geostrophic shear always exists due to. To the high-frequency wind and Kuroshio intrusion, it is unclear which is more important?

Reply: The near-inertial variability in the ocean are mainly caused by wind variability through the resonance between the wind and the ocean current (Gill,1984).Although the Kuroshio intrusion is low-frequency process, it can provide the background field for the vertical propagation through the chimney effect(Lee and Niiler 1998; Zhai et al. 2005) because negative vorticity west of the Kuroshio in the Luzon Strait always exists. When the Kuroshio intrusion is from one state to the other state (looping state to leaping state for example, Nan et al,2015), the geostrophic adjustment will also trigger near-inertial waves. This similar process is well depicted by Takeyoshi et al(2015).The reviewer just provide a very important and interesting question of relative importance of high-frequency wind and Kuroshio intrusion which need more observational and simulated work in the future study.

Ref:

A. E. Gill, 1984: On the Behavior of Internal Waves in the Wakes of Storms. J. Phys. Oceanogr., 14, 1129–1151.

Lee, D. K., and P. P. Niiler, 1998: The inertial chimney: The near-inertial energy drainage from the ocean surface to the deep layer. J. Geophys. Res., 103, 7579–7591.

Zhai, X., R. J. Greatbatch, and J. Zhao, 2005: Enhanced vertical propagation of storm-induced near-inertial energy in an eddying ocean channel model. Geophys. Res. Lett., 32, L18602, doi:10.1029/2005GL023643.

F. Nan, H. Xue, F. Yu, 2015: Kuroshio intrusion into the South China Sea: a review.Prog. Oceanogr., Vol. 137(A), 314-333.

Takeyoshi Nagai,Amit Tandon, Eric Kunze, and Amala Mahadevan, 2015: Spontaneous Generation of Near-Inertial Waves by the Kuroshio Front. J. Phys. Oceanogr., 45, 2381–2406.

2. The statement and the cited literature of the third paragraph seems not support the conclusion “SCSMOC variability spans a wide range of time scales”. The introduction is not well written.

Reply: The SCSMOC represents the connection between the deep circulation and the upper circulation in SCS. The Luzon Strait transport plays an important role in the SCSMOC, so we first depict the Luzon Strait transport in the first paragraph, and then we just describe the structure of the climatological SCSMOC. Finally, we just state the variability of the SCSMOC from the decadal scale to seasonal scale, but there is no study for the more high-frequency variability of the SCSMOC. “SCSMOC variability spans a wide range of time scales” is just qualitative description, not the conclusion. Our study is inspired by the near-inertial variations of AMOC because near-inertial internal waves have been believed to be an important energy source for the diapycnal mixing in the ocean required to maintain the meridional overturning circulation (MOC) (Munk and Wunsch 1998; Blaker et al., 2012; Sévellec et al., 2013). We are just sorry for the sketchy statement in fourth paragraph in our introduction. And the fourth paragraph in our introduction has been revised.

Ref:
Munk, W., and C. Wunsch, 1998: Abyssal recipes II, Energetics of tidal and wind mixing. Deep Sea Res. I, 45, 1977–2010.
Blaker, A. T., Hirschi, J. J. M., Sinha, B., de Cuevas, B., Alderson, S., Coward, A., and Madec, G.: Large near-inertial oscillations of the Atlantic meridional overturning circulation, Ocean Model., 42, 50–56, 2012.
Sévellec, F., Hirschi, J. J. M., and Blaker, A. T.: On the Near-Inertial Resonance of the Atlantic Meridional Overturning Circulation, J. Phys. Oceanogr., 43, 2661–2672, 2013.

3. In section 2, the model results should be validated against the observations. I recommend you to verify the model output using the mooring observations shown in Fig. 7 in order to get credible conclusions.

Reply: Strictly speaking, the observational system in full depth used as the validation of the simulated SCSMOC should consists of some typical latitude section cross the South China Sea like Rapid Climate Change–Meridional Overturning Circulation (RAPID-MOC) at 26.58^{o}N in Atlantic. The previous study also suggest that the near-inertial AMOC variability is nearly invisible to AMOC-observing systems because of high-frequency observational sampling for near-inertial variation (Blaker et al., 2012 ;Sévellec,et al., 2013). Most of observational data focus on the 18^{o}N section in the SCS, and the observational depth is just shallow then 2000m. Especially, We have no such observation system for the monitoring of the near-inertial variations of SCSMOC. So we just use the mooring data in deep SCS to validate the model output, as shown in Figure C1.The power spectrum of the model output is similar to that of the observation data. And the model can produce the near-inertial variations in the deep SCS, which can validate the near-inertial variations of SCSMOC in our model data to a certain extent. We will replace Figure 7 with Figure C1 in the final manuscript.

Ref:
Blaker, A. T., Hirschi, J. J. M., Sinha, B., de Cuevas, B., Alderson, S., Coward, A., and Madec,G.: Large near-inertial oscillations of the Atlantic meridional overturning circulation, Ocean Model., 42, 50–56, 2012.
Sévellec, F., Hirschi, J. J. M., and Blaker, A. T.: On the Near-Inertial Resonance of the Atlantic Meridional Overturning Circulation, J. Phys. Oceanogr., 43, 2661–2672, 2013.

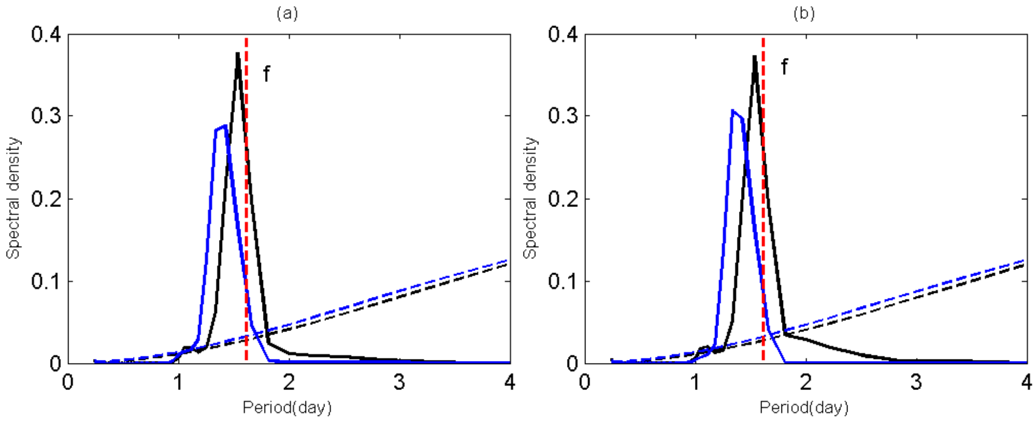

Figure C1 The power spectrum of zonal velocity (a) and meridional velocity (b) derived from the mooring (black line) and GLBu0.08 (blue line). The dashed black and blue line shows 95% confidence levels. The dashed red line represents the local inertial period. The tide effects have been removed in the mooring data.

4. It should be explained why GLBu0.08 product only in 2010 is chosen (see last sentence in Section 2)?

Reply: We also use model outputs of four typical month(January, April, July and October)in three years(2000,2006,2010) to show whether near-inertial variations of the SCSMOC also exist in other seasons and any other years, as shown in Figure C2(2000), Figure C3(2006), Figure C4(2010).Our results show that these near-inertial variations of the SCSMOC exists in other seasons and other years. The analysis of other months or years cannot change our conclusion significantly, so we just use the 2010 data to depict the near-inertial variations of the SCSMOC.

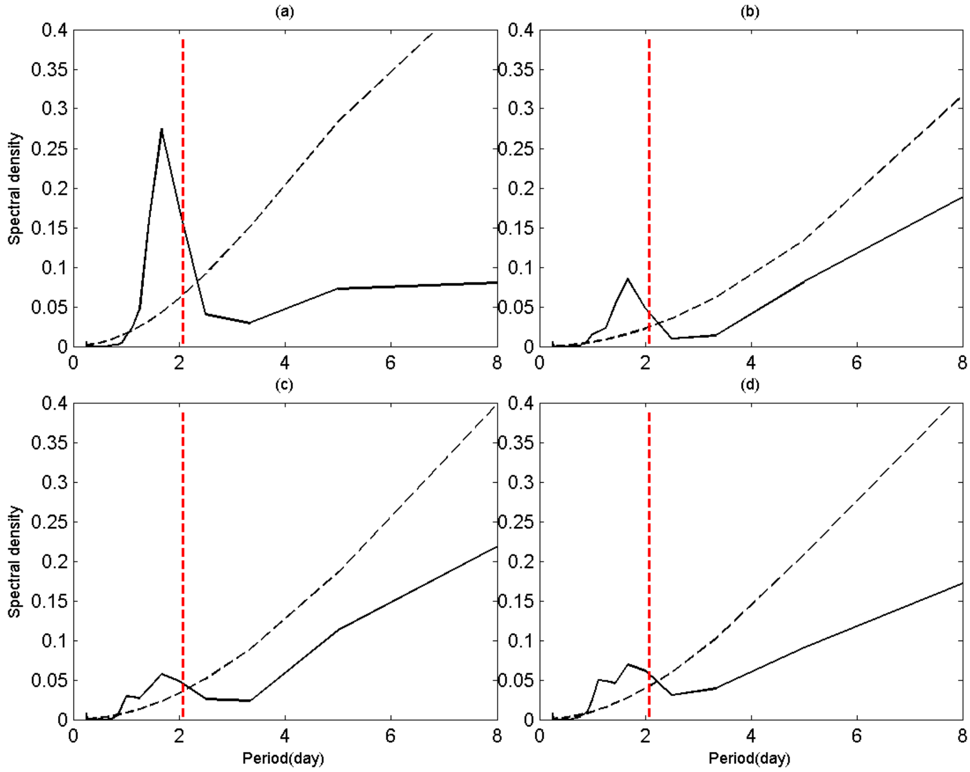

Figure C2 The power spectrum of SCSMOC at 1500m, 14^{o}N in (a) January,(b) April, (c) July and (d) October in 2000. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

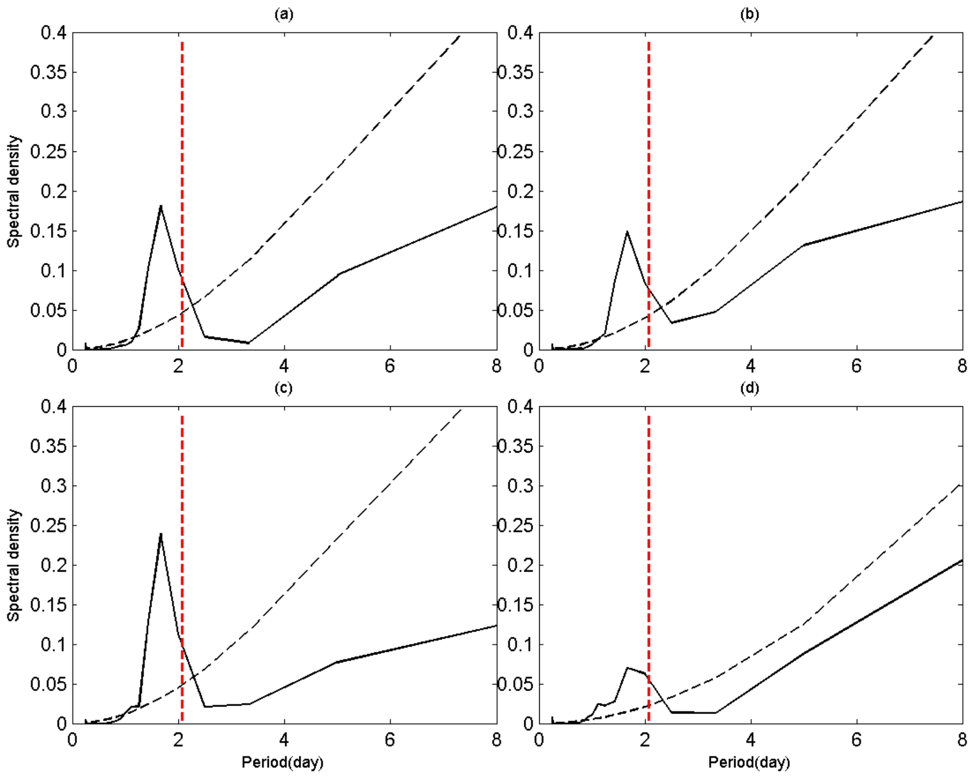

Figure C3 The power spectrum of SCSMOC at 1500m, 14^{o}N in (a) January,(b) April, (c) July and

(d) October in 2006. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

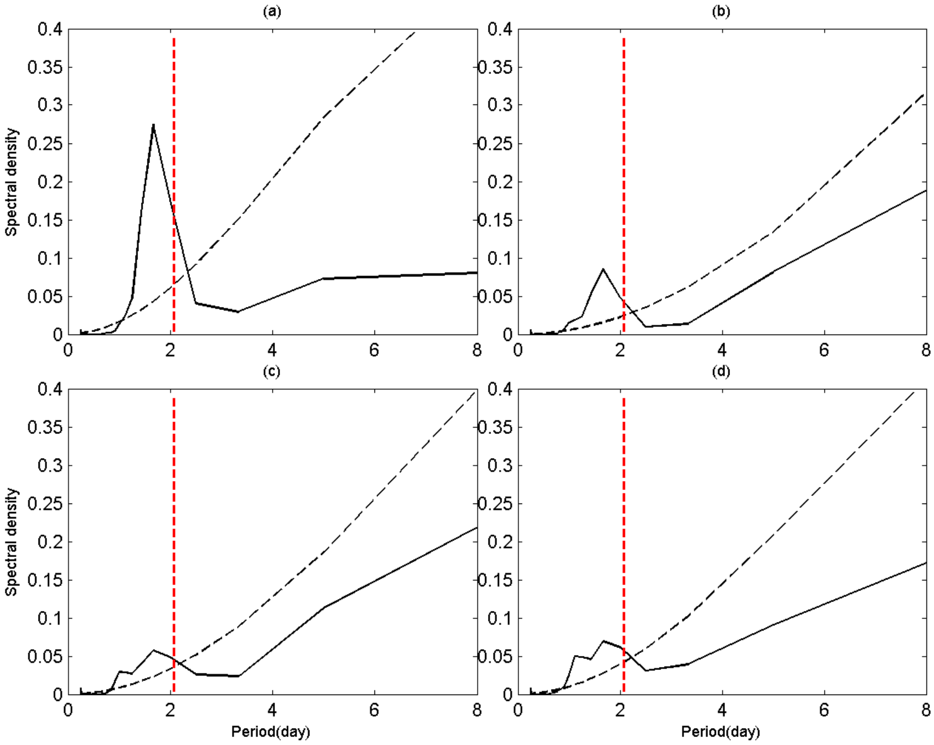

Figure C4 The power spectrum of SCSMOC at 1500m, 14^{o}N in (a) January,(b) April, (c) July and (d) October in 2010. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

5. Why 1500 m and 14°N are selected in Fig. 2 to investigate the deep SCSMOC?

Reply: We use SCSMOC index as the stream function at a depth of 1500m at 14°N, because this point is far away from the Luzon Strait. We have checked the SCSMOC index in the different latitude and depth, as shown in Figure C5 and C6. Actually, the analysis of the index of the SCSMOC in other latitude and depth is nearly the same to the stream function at a depth of 1500m at 14^{o}N for the near-inertial variations of SCSMOC, and cannot change our conclusion of the present study.

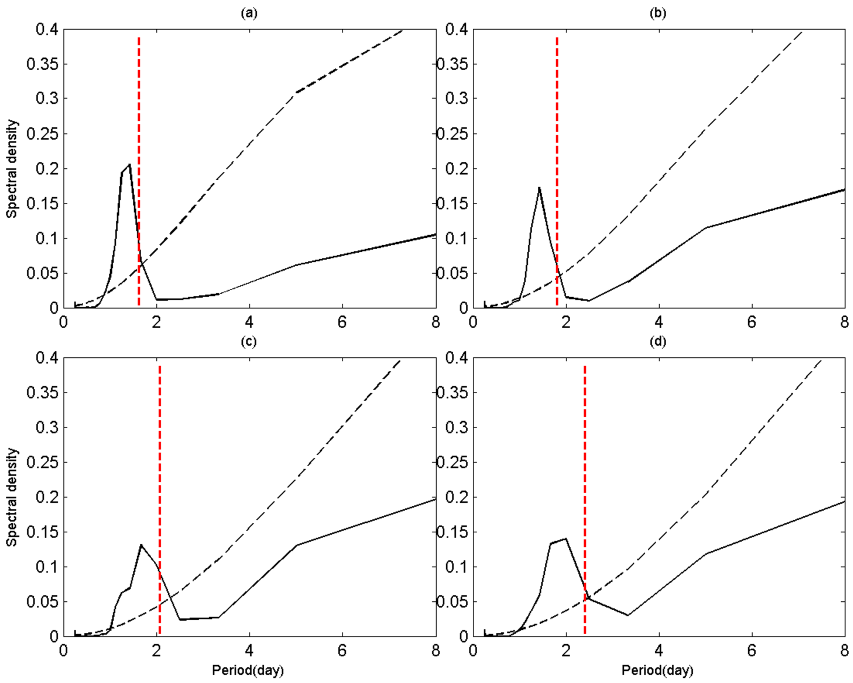

Figure C5 The power spectrum of SCSMOC at 1500m,**18^{o}N**(a),1500m,**16^{o}N**(b),1500m, **14^{o}N**(c) ,and 1500m, **12^{o}N**(d) during January in 2010. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

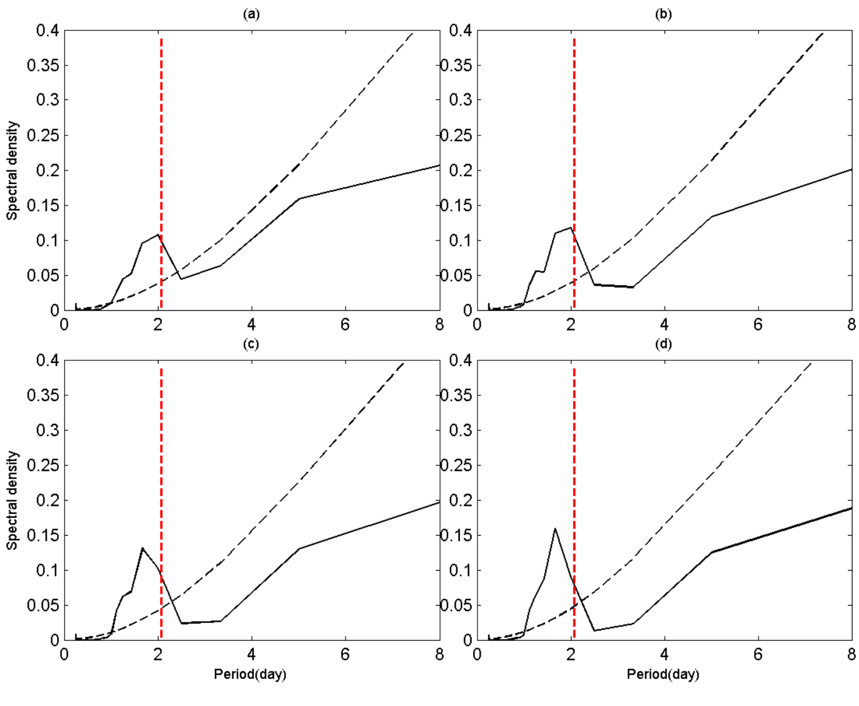

Figure C6 The power spectrum of SCSMOC at **500m**,14^{o}N(a),**1000m**,14^{o}N(b),**1500m**, 14^{o}N(c) ,and **2000m**, 14^{o}N(d) during January in 2010. The dashed black line and red line show 95% confidence levels and the local inertial period respectively.

6. "The pattern of the near-inertial variability of SCSMOC (Fig. 4b) is very similar to the near-inertial variability of the Pacific Ocean or Atlantic." (see third paragraph in Section 3). Any reasons?

Reply: The imprint of NIGWs in AMOC is also stacked with regularly alternating positive and negative cells in the depth between 500 to 4000m and within the latitude between 10 and 40^{o}N (Komori et al., 2008;Blaker et al., 2012; Sévellec et al., 2013). The period corresponding to the power peak of AMOC is at super-inertial periods, which is similar to that of SCSMOC. Actually , the imprint of NIGWs in AMOC and SCSMOC is equatorial propagation because of beta effect of NIGWs (Anderson and Gill, 1979; Garrett, 2001).

The litter difference is that the imprint of NIGWs on AMOC has been found mostly triggered by wintertime storm tracks which is in mid-latitude, so the near-inertial phase velocity is larger than that in SCS which is in the low-latitude.

Ref:

Blaker, A. T., Hirschi, J. J. M., Sinha, B., de Cuevas, B., Alderson, S., Coward, A., and Madec, G.: Large near-inertial oscillations of the Atlantic meridional overturning circulation, Ocean Model., 42, 50–56, 2012.

Komori, N., Ohfuchi,W., Taguchi, B., Sasaki, H., and Klein, P.: Deep ocean inertia-gravity waves simulated in a high-resolution global coupled atmosphere–ocean GCM, Geophys. Res. Lett., 35, L04610, doi:10.1029/2007GL032807, 2008.

Sévellec, F., Hirschi, J. J. M., and Blaker, A. T.: On the Near-Inertial Resonance of the Atlantic Meridional Overturning Circulation, J. Phys. Oceanogr., 43, 2661–2672, 2013.

Anderson, D. L. T. and Gill, A. E.: Beta dispersion of inertial waves, J. Geophys. Res.-Oceans,84, 1836–1842, 1979.

Garrett, C.: What is the “near-inertial” band and why is it di□erent from the rest of the internal wave spectrum?, J. Phys. Oceanogr., 31, 962–971, 2001.

On the near-inertial variations of meridional overturning circulation in the South China Sea

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Abstract

We analyze the near-inertial variability of the meridional overturning circulation in the South China Sea (SCSMOC) based on a global 1/12° ocean reanalysis. The wavelet analysis and power spectrum of deep SCSMOC time series shows that there is a significant signal of the near-inertial band. The maximum amplitude of the near-inertial signal in the SCSMOC is nearly 4Sv. The spatial structure of the signal features regularly alternating counterclockwise and clockwise overturning cells. It is also found that the near-inertial signal of SCSMOC mainly originates from the region near the Luzon Strait and propagates equatorward with the speed of 1-3 m/s. Further analyses suggest that the near-inertial signal in the SCSMOC is triggered by high-frequency wind variability near the Luzon Strait, where geostrophic shear always exists due to Kuroshio intrusion.

Key words: SCSMOC; near-inertial variability; Kuroshio.

1 Introduction

The widest and deepest channel in the South China Sea (SCS) is the Luzon Strait, which has a sill depth of about 2400m, and is the main passage connecting the SCS and the northwestern Pacific Ocean (Qu et al., 2006). Previous studies show that the SCS acts as a mixing mill that mixes the surface and deep waters and returns the mixed waters out of the Luzon Strait at an intermediate depth (Yuan, 2002; Tian et al., 2009; Yang et al., 2013, 2014). Based on field observations, studies confirm the hypothesis that the Luzon Strait transport (LST) has a sandwiched vertical structure, which shows a westward flow in the upper layer (<500 m) and in the deeper layer (>1500 m), and an eastward flow in the intermediate layer (500–1500 m, Tian et al., 2006; Yang et al., 2010). The corresponding circulation in the SCS is consistent with the potential vorticity constraint (Yang et al., 2000 and 2007), which suggests that the mixing-induced circulation inside the SCS should be cyclonic gyres at the surface and at the bottom (Chao et al., 1996; Li et al., 2006; Wang et al., 2011; Lan et al., 2013; Xu et al., 2014), and an anti-cyclonic gyre at an intermediate depth (Isobe et al., 2001; Yuan, 2002). Note that the upper-layer SCS circulation is also affected by the seasonally reversing monsoon, exhibiting a cyclonic circulation over the whole SCS basin in winter, and in summer a strong anti-cyclonic circulation in the southern SCS and a weak cyclonic circulation in the northern SCS (Wrytki, 1961; Chu et al., 1999; Chu and Li, 2000; Qu, 2000; Hu et al., 2000; Liu et al., 2001; Wang et al., 2003; Su, 2004).

In the context of the strong mixing in the SCS and the sandwiched vertical structure of the Luzon Strait transport, Wang et al. (2004) proposed that the shallow meridional overturning in the SCS (SCSMOC) is semi-enclosed, transporting waters from north to south at the depth of about 500m (200 m) and returning waters to north at surface in winter (summer). The shallow SCSMOC hints at a transport path such that intermediate water enters the SCS from the northwestern Pacific Ocean (Wang et al., 2004; Xie et al., 2013). Zhang et al. (2014)[1] further show that the shallow SCSMOC

[1] Zhang, N., Lan, J., and Cui, F.: The shallow meridional overturning circulation of the South China Sea, Ocean Sci. Discuss., 11, 1191–1212, doi:10.5194/osd-11-1191-2014, 2014.

consists of downwelling in the northern SCS, a southward subsurface branch supplying upwelling in the southern SCS and a northward return flow of surface water. Based on the high-resolution global reanalysis data (GLBa0.08), Shu et al. (2014) found that the whole SCSMOC also has a sandwiched structure driven by the Luzon Strait transport, consisting of a stronger semi-enclosed clockwise overturning circulation in the upper layer, a weaker counterclockwise overturning circulation in the intermediate layer, and a weaker clockwise overturning circulation in the deep layer.

The SCSMOC variability spans a wide range of time scales. On a decadal time scale, the intermediate water of the SCS was fresher in the 1980s than that in the 1960s, caused by the deep SCSMOC decreasing from the 1960s to the 1980s according to an ocean reanalysis (Liu et al., 2012). On the interannual scale, the Luzon Strait transport shows a remarkable inter-annual variability associated with El Niño-Southern Oscillation (ENSO, Qu et al., 2004). The upper LST correlates with the local wind stress while the lower LST shows a statistically significant correlation with Nino3.4 index (Qu et al., 2005; Wang, D. et al., 2006; Wang, Y. et al., 2006), indicating that the shallow SCSMOC also has an interannual variability related with ENSO. On a seasonal scale, the seasonal variability of the shallow SCSMOC mostly controls the strength of seasonal intrusions of the North Pacific Water into the SCS (Liu et al., 2008). Moreover, the deep overflow through the Luzon Strait is strong in summer while weak in winter, driving the seasonal variability of the deep SCSMOC (Lan et al., 2015). However, there is no study so far for shorter time-scale variability (especially for near-inertial variation) of the SCSMOC.

Near-inertial internal waves have been considered to be an important energy source for the diapycnal mixing in the ocean required to maintain the meridional overturning circulation (MOC, Munk et al., 1998).The existence of near-inertial (several days) variability of the Atlantic meridional overturning circulation (AMOC) has been recently reported by using a high-resolution oceanic general circulation model (Blaker et al., 2012). This variability is associated with equatorward-propagating near-inertial gravity waves (NIGWs). Whether high frequency (near-inertial) variability exists in the SCSMOC is the main purpose of this study. The rest of the paper is organized as follows. The data and methods are introduced in Sect. 2. The results are presented in Sect. 3. Sections 4 and 5 give discussion and conclusion.

2 Data and Method

The product of Hybrid Coordinate Ocean Model+Navy Coupled Ocean Data Assimilation (HYCOM+NCODA) global 1/12° Reanalysis (GLBu0.08, http://hycom.org/dataserver/glb-reanalysis) provided by the Naval Research Laboratory is used in this study. As a dynamical model, HYCOM 2.2 is configured for the global ocean with the bathymetry derived from the 30 arc-second GEBCO (General Bathymetric Chart of the Oceans) dataset. The K-Profile Parameterization (KPP) mixing scheme is adopted for the vertical diffusion of momentum, temperature, and salinity (Thoppil et al., 2011). The model is forced by the hourly wind stress and heat fluxes derived from National Center for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) with horizontal resolution of 0.3125°. Note that there is no tidal forcing during the integration. It is initialized using temperature and salinity from the 1/4° Generalized Digital Environmental Model (GDEM4) climatology in January. The NCODA assimilates available satellite altimeter observations, satellite and in-situ sea surface temperature (SST) as well as available in-situ vertical temperature and salinity profiles from XBTs, Argo floats and moored buoys using a 3-D variational scheme (Cummings, 2005). The model output is stored every 3 h.

Based on the equation of continuity, the meridional overturning streamfunction can be defined as (Endoh et al., 2007):

$$\frac{\partial \psi(y,z,t)}{\partial z} = \int_{x_e}^{x_w} v(x,y,z,t)dx \quad (1)$$

$$\frac{\partial \psi(y,z,t)}{\partial y} = -\int_{x_e}^{x_w} w(x,y,z,t)dx \quad (2)$$

Because there is no vertical velocity (w) provided in GLBu0.08, the meridional overturning streamfunction in SCS could be calculated as:

$$\psi(y,z,t)=\int_{-H}^{z}dz\int_{x_e}^{x_w}v(x,y,z,t)dx \quad (3)$$

where x_w and x_e are the western and eastern limits of the basin, respectively, and H is the ocean bottom. Although the meridional overturning streamfunction is calculated only by the meridional velocity (v), it also represents the integrated vertical motions in the basin because of the equation of continuity (Endoh et al., 2007). Shu et al. (2014) have used another product of HYCOM+NCODA global 1/12° Reanalysis (GLBa0.08, Fig. 1a) to depict the structure of the SCSMOC. The only difference between GLBa0.08 and GLBu0.08 is the external forcing field. GLBa0.08 is forced by Navy Operational Global Atmospheric Prediction System (NOGAPS), while GLBu0.08 is driven by Climate Forecast System Reanalysis (CFSR). Figure 1 shows the SCS meridional overturning stream function averaged from 2004 to 2010 based on GLBa0.08 and GLBu0.08. It is found that the two products show roughly a similar SCSMOC, which consists of a semi-enclosed clockwise upper overturning cell, a counterclockwise intermediate overturning cell and a clockwise deep overturning cell as shown in Fig. 1. The main difference is that the intermediate cell in GLBu0.08 is stronger and the deep cell stretches less southward compared with the GLBa0.08. And the upper cell in GLBu0.08 is deeper. More importantly, compared with the daily-output GLBa0.08, GLBu0.08 has a three-hour output, which is better for studying motion with periods of only a couple of days. So the GLBu0.08 product in 2010 is chosen to analyze the characteristics of near-inertial variability of the SCSMOC in this study.

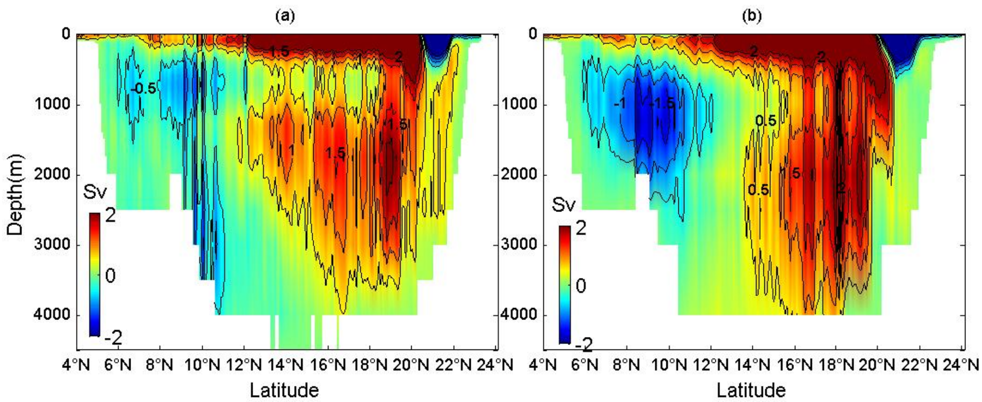

Figure 1. SCSMOC averaged from 2004 to 2010 based on GLBa0.08 (a) and GLBu0.08 (b).

3 Characteristics of the near-inertial variability of the SCSMOC

Figure 2a shows the 120-day time series of the deep SCSMOC (at 1500 m and 14°N) since 1 January, 2010. It is found that the SCSMOC experiences an obvious intra-seasonal variability superimposed with persistent high-frequency undulations (Fig. 2a). The wavelet analysis shows that the high-frequency undulations are corresponding to strong and persistent power on the band of 1-3 days while the intra-seasonal variability has power with periods of about 16-32 days (Fig. 2b). The spectral analysis further confirms that there is an obvious period band of 1–3 days in the deep SCSMOC time series (Fig. 2c). It is also found that the period corresponding to the power peak of SCSMOC is prolonged equatorward from 1 day at 20°N to 3 days at 10°N (Fig. 3a). It is noted that the near-inertial band in the SCS is from 1.46 days at 20°N to 3.59 days at 10°N (Chen et al, 2014). Comparing with the local inertial period in the SCS, the deep SCSMOC is at super-inertial periods (the period corresponding to the power peak is less than the local inertial period), while the shallow SCSMOC is at inertial periods. However, the SCSMOC between 8°N and 10°N is at sub-inertial periods (the period corresponding to the power peak is larger than the local inertial period).

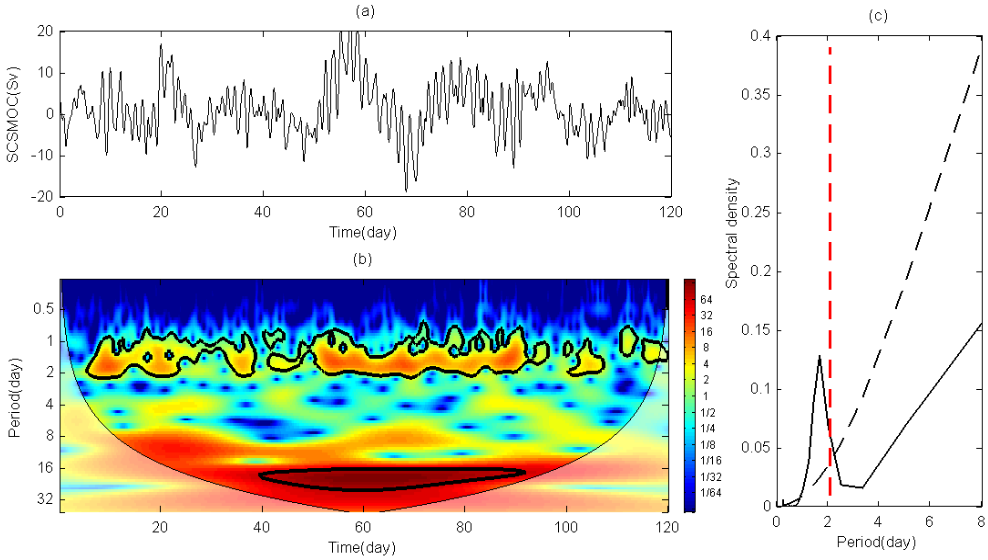

Figure 2 (a) Time series of SCSMOC at 1500m, 14°N; (b) The continuous wavelet power spectrum (black contours representing 95% significance); (c) The power spectrum (the dashed black line and red line show 95% confidence levels and the local inertial period respectively).

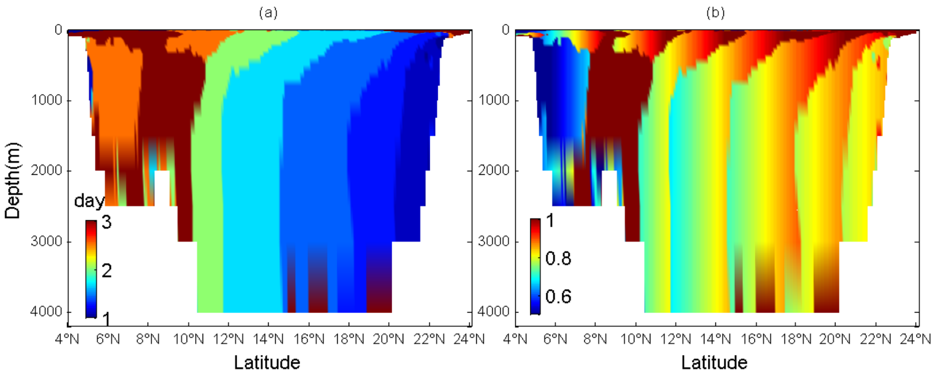

Figure 3 (a) The period corresponding to the power peak of the SCSMOC, which passes 95% significance; (b) The ratio of the peak period of the SCSMOC to the local inertial period.

To extract the near-inertial signal of the SCSMOC, a third-order Butterworth filter is applied to the time series of the SCSMOC at each latitude and depth. Cutoff frequencies are set at [0.33, 1] cpd, which is corresponding to the 1-3day band. The maximum standard deviation (STD) of the filtered SCSMOC signal is nearly 4 Sv (Fig. 4b), nearly half of the maximum STD of total SCSMOC in 2010 (Fig. 4a). The largest amplitude of the near-inertial signal in SCSMOC is found in mid layer (500–2500 m). There are two high STDs at the mid depth (500–2500 m), the northern one is between 16°N and 20°N, and the southern one between 12°N and 14°N (Fig. 4b). Near the Luzon Strait (around 19°N in Fig. 4b) there exists a maximum of the shallow SCSMOC variability in the layer (100–500 m).

Based on the snapshot of the integrated filtered meridional velocity field from the bottom to 1000m at 24:00, January 15, 2010 (Fig. 5a), it is obvious that the integrated velocity field consists of regularly alternating positive and negative bands. Furthermore, Fig. 5b is the snapshot of the filtered SCSMOC signal at the same time as in Fig. 5a. The spatial structure of the near inertial signal is stacked with regularly alternating positive and negative cells. The maximum amplitude of these cells is nearly 5Sv, and most of the cells concentrate in the depth between 1000m to 2500m and within the latitude between 10°N and 20°N while the cells are not so evident in the upper layer. These cells are stretched not in the meridional direction but in the vertical direction, which means each cell consists of both the strong upwelling branch and the downwelling branch. From 4°N to 10°N and 20°N to 22°N, there are also weak cells. The upwelling and downwelling in the mid depths are also found in the open ocean like the Atlantic and Pacific Oceans based on the high-resolution model simulations where the vertical velocity was used to diagnose the deep ocean near-inertial gravity waves (Komori et al., 2008; von Storch, 2010). The pattern of the near-inertial variability of SCSMOC (Fig. 4b) is very similar to the near-inertial variability of the Pacific or Atlantic Oceans. The imprint of NIGWs in AMOC is also stacked with regularly alternating positive and negative cells in the depth between 500 to 4000m and within the latitudes between 10 and 40°N (Komori et al., 2008; Blaker et al., 2012; Sévellec et al., 2013). The period corresponding to the power peak of AMOC is at super-inertial periods, which is similar to that of the SCSMOC.

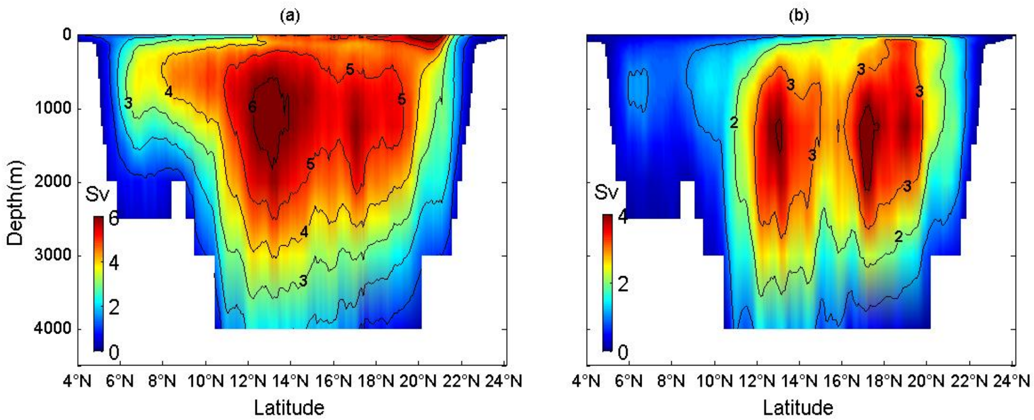

Figure 4 (a) The standard deviations of the SCSMOC in 2010and (b) The filtered 1-3day SCSMOC signal in 2010.

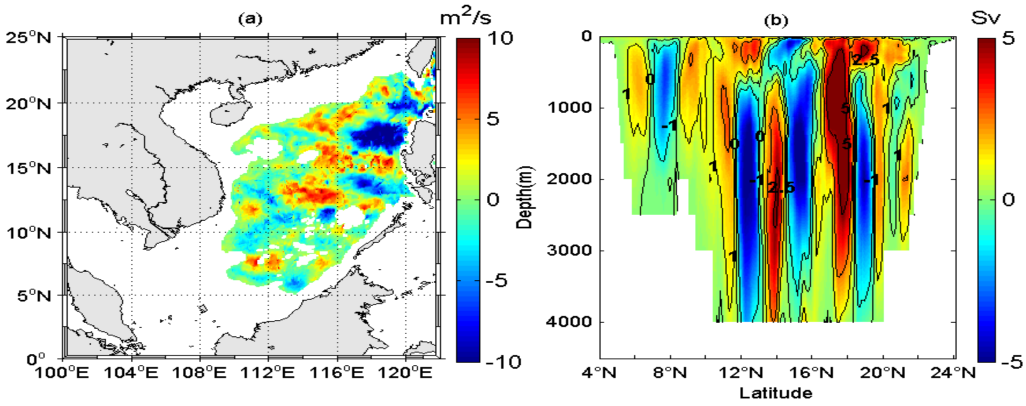

Figure 5 The snapshot of (a) the integrated meridional velocity field from the bottom to 1000m and (b) the filtered SCSMOC signal at 24:00, January, 2010.

To investigate the meridional propagation of near-inertial signals in the SCSMOC in mid-depths (500–2500m), Fig. 6 shows the meridional structure of the filtered near-inertial signal at 1500m in four typical months (January, April, July and October) in 2010. It is found that most of the signal propagates from the region near the Luzon Strait (where 18°N is the latitude of the southern tip of the Luzon Strait in Fig. 6) regardless of the different months. The propagating velocity is about 1-3 m/s. It was noted that the NIGWs usually have the dominant frequency of f (Coriolis frequency) and usually propagate equatorward due to beta-dispersion (Anderson and Gill, 1979; Nagasawa et al., 2000; Garrett, 2001). The meridional propagation of the filtered SCSMOC signal and near inertial period (Fig. 3b) indicate that the striped pattern of the filtered 1-3day SCSMOC signal represents ocean NIGWs formed especially near the Luzon Strait and propagating equatorward.

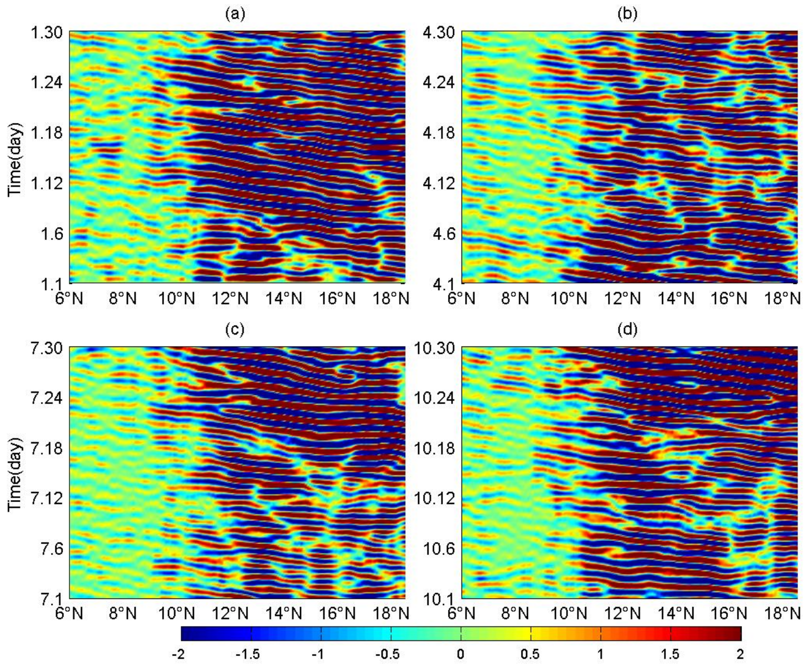

Figure 6 Time-latitude plot of 1-3day band-passed SCSMOC signal at 1500m in (a) January, (b) April, (c) July and (d) October in 2010.

4 Discussion

The East Asian monsoon system prevails over the SCS, where strong tropical cyclones frequently originating from the western Pacific affect (Zheng et al., 2015). Strong vertical mixing and horizontal pressure gradients caused by typhoon winds can lead to the formation of strong NIGWs in the ocean interior (Garrett, 2001). Previous observations of NIGWs are focused on the upper layer in the SCS (Liang et al., 2005; Xie et al., 2009; Xu et al., 2013; Chen et al., 2013), only Yuan et al. (2002) have found there are strong NIGWs below 1800m in the northeastern SCS using two current-meters. The mooring was located at 114.57°E, 17.99°N, where the water depth is about 3500m. An Aanderaa current-meter was positioned at 300 m above the bottom and the valid current-meter data were collected from March 21, 2006 to September 19, 2006 with the sampling interval of 1 h. The 120-day data since April 1, 2006 was used in this study. The power spectrum of zonal velocity and meridional velocity in the mooring data and model output peaks nearly peaks at the near-inertial frequency (Fig. 7).

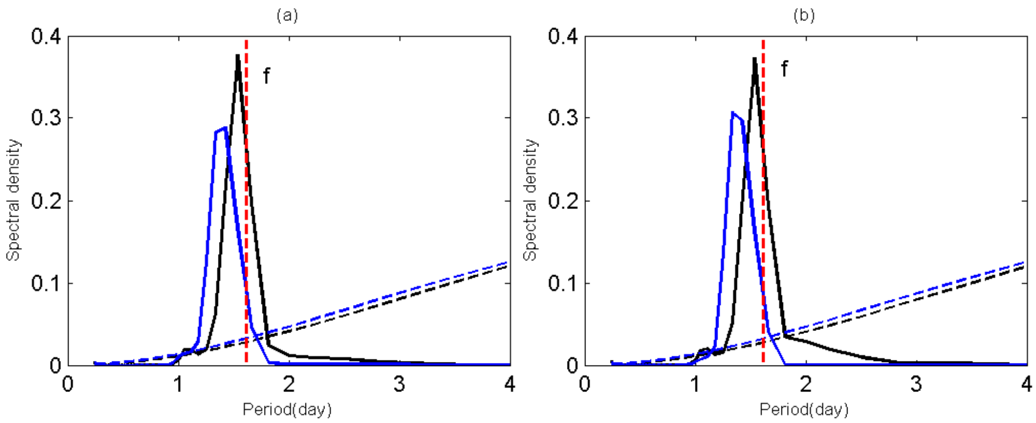

Figure 7 The power spectrum of zonal velocity (a) and meridional velocity (b) derived from the mooring (black line) and GLBu0.08 (blue line). The dashed black and blue line shows 95% confidence levels while the dashed red line represents the local inertial period. The tide effects have been removed in the mooring data.

The near-inertial variability in the ocean are mainly caused by wind variability through the resonance between the wind and the ocean current (Gill, 1984).The imprint of NIGWs on AMOC has been found mostly related to wintertime storm tracks (Blaker et al., 2012; Sévellec et al., 2013; Furuichi et al., 2013; Rimac et al., 2013) while the imprint of NIGWs on SCSMOC might be related to wind variability near Luzon Strait (Li et al., 2015). Figure 8 further shows the monthly mean near-inertial energy input by wind during four representative months (January, April, July and October) in 2010. It is found that wind-induced near-inertial energy input is always strong west of the Luzon Strait. In spring, autumn and winter, these strong high-frequency wind wakes in the Luzon Strait could drive the NIGWs near the Luzon Strait (Fig. 8a–b and d). An average of about 7 TCs pass through the Luzon Strait from the Northwest Pacific Ocean each year (Wang et al., 2007; Zheng et al., 2015), especially there were 2 TCs on July 2010 and 1 TC on October 2010 passing through the region to the west of the Luzon Strait, inducing strong wind-induced near-inertial energy input into the ocean (Fig. 8c), so TCs could also be drivers of the NIGWs near the Luzon Strait. The horizontal distribution of large integrated near-inertial kinetic energy roughly corresponds to that of the strong wind-induced near-inertial energy input (Figs. 8 and 9). In addition, due to beta-dispersion of the

NIGWs (Anderson and Gill, 1979; Garrett, 2001), the region of the integrated near-inertial kinetic energy is stretched equatorward. Furthermore, a strong density front usually exists in the Luzon strait due to the Kuroshio (Wang et al., 2001), inducing positive vorticity west of the Kuroshio and negative vorticity to its east. On the one hand, the disturbance of the front (Kuroshio) can drive NIGWs through geostrophic adjustment (Kunze, 1985; Wang et al., 2009; Whitt et al., 2013). On the other hand, the transfer of near-inertial energy to the deep ocean can be enhanced by the negative vorticity field (Lee et al., 1997; Zhai et al., 2005). As the NIGWs leave the density front, they will propagate equatorward due to beta-dispersion (Anderson and Gill, 1979; Garrett, 2001). Therefore, strong NIGWs near the Luzon Strait can be detected in the deep SCSMOC south of the Luzon Strait as far as 10°N.

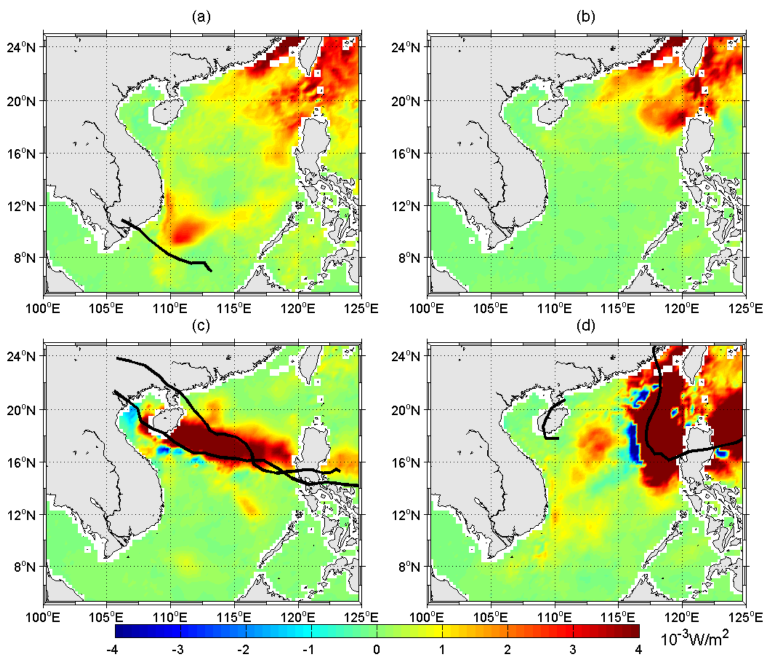

Figure 8 Spatial distribution of the monthly mean near-inertial energy input by wind in (a) January, (b) April, (c) July and (d) October in 2010. The black line is the best track of TC derived from the Joint Typhoon Warning Center (JTWC).

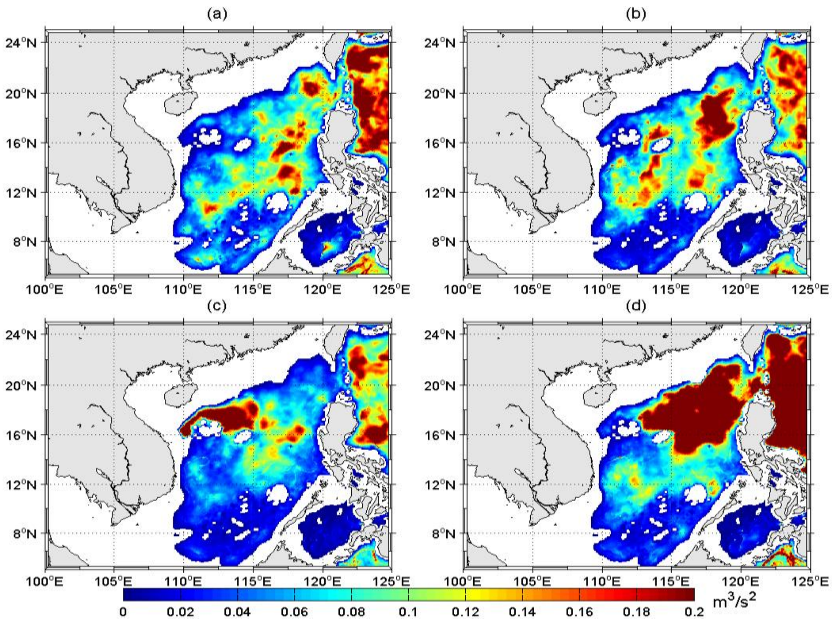

Figure 9 The monthly mean integrated near-inertial kinetic energy from the bottom to 1000m in (a) January, (b) April, (c) July and (d) October in 2010.

5 Conclusion

A high-resolution ocean reanalysis (GLBu0.08) is used to reveal the characteristics of the near-inertial variability in the deep SCSMOC. It is shown that there is an obvious high power peak on the near-inertial band in the deep SCSMOC time series. The maximum amplitude of the near-inertial signal in the SCSMOC is nearly 4 Sv. And the large amplitude of the near-inertial signal in SCSMOC is found in the mid layer (500–2500m).The near-inertial signal in SCSMOC propagates equatorward with the speed of 1-3m/s from the region near the Luzon Strait. The imprint of NIGWs on the SCSMOC highlights the possible importance of NIGWs in the horizontal and vertical redistribution of wind energy throughout the SCS. Although the effect of these NIGWs in depth on turbulent mixing is still unknown, however, it is speculated that the breaking of these deep ocean NIGWs could be a candidate for the enhanced mixing in the SCS.

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