Response to the comments of Anonymous Referee #1

Interactive comment on "Decadal variability of heat content in the South China Sea inferred from observation data and an ocean data assimilation product" by W. Song et al.

Received and published: 23 September 2013

Dear reviewer,

Sorry to reply the comments so lately. I took part in an oceanographic survey which took longer than expected because of the bad weather.

In this paper the authors consider the contributions of surface fluxes and ocean heat advection to the change in upper ocean heat content in the South China Sea. To do this they use data from an ocean data assimilation (SODA) and surface fluxes from an atmospheric reanalysis (NCEP). During the timeframe 1958-2003 they identify four periods in which the heat content of the South China Sea decreases, increases, decreases and finally increases again. Furthermore they find that in the first two periods, up to 1981, advection dominates the heat content change while in the second two periods, from 1982 onwards, surface fluxes are the principal cause of heat content change. As such the article is interesting and worth publication.

- Thanks for your recommendation and valuable comments. Below are our responses to the comments.

So far as I can see the XBT data is only used to compare it to the SODA results, which presumably contain the XBT data anyway. One important question is whether these data have been corrected for the well-known problem with XBT data in the 1970s when an error in the equation linking the depth to the falling time led to errors in the temperature-depth relationship and hence errors in heat content. Another important question relates to the spatial distribution of data within the region. Over the timeframe in question political interests in the region have changed considerably and this may have affected the spatial distribution of data collection.

- We haven't noticed the falling rate error of XBT in the 1970s, the random error is generally assumed to be 1%–2% of depth (Carton et al. 1999). The SODA product has modified the error, as shown in figure 2 (bottom), the XBT and SODA has no evident difference in the 1970s, so we believe that the falling rate error of XBT has little influence to our study.

  We admit that the temporal and spatial distribution of XBT is

irregular and it can affect the study, using SODA product can solve this issue well after comparing the SODA and XBT.

The introduction contains some assertions not supported by references, for example p1331, lines 7-8.

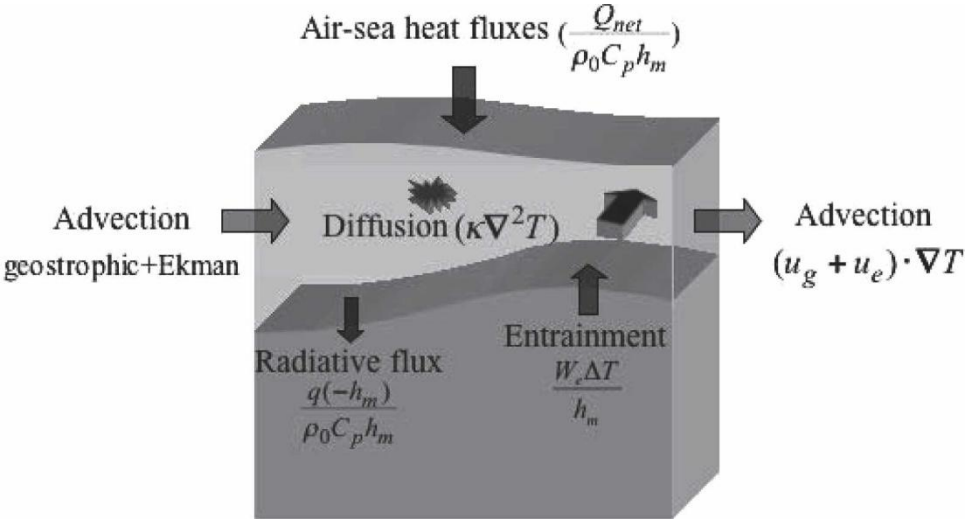
- The reference is added.

In the Methods section on p1332 there needs to be more detail of the budget equation. In particular to distinguish between horizontal and vertical advection and horizontal and vertical diffusion, so that it is clear what is contained in the each of the terms in what I presume is the budget equation: HCC = QNET + ADV + R, which also needs to be explicitly written somewhere so that we know what the signs of the terms are, rather than guessing them from Table 1.

- Yes, the budget equation is the formula you gave above, it's the simplification of the original budget equation, as following,

$$\frac{\partial T_m}{\partial t} = \frac{Q_{\text{net}} - q(-h_m)}{\rho_0 c_p h_m} - \mathrm{u_m} \cdot \nabla T_m + \kappa \nabla^2 T_m - \frac{w_e \Delta T}{h_m}$$

(Dong et al., 2007, JC)



(**Dong et al., 2007, JC)**

As the Schematic diagram above shown, we choose the air-sea heat flux (QNET), advection (ADV, horizontal only) and heat content change (or temperature variation, HCC), and put the other terms together into the residual heat flux(R).

We add the description of the balance equation into the article.

I presume the heat content is the integral of the Celsius temperatures over the top 400m multiplied by the density and specific heat, but this needs to be said. Admittedly only anomalies and changes are discussed, so that the reference temperature (zero Celsius) is arbitrary. Since XBTs usually reach 700 m depth I wonder why the authors only used 400 m?

- Yes, the heat content is the integral of the Celsius temperatures over the top 400m. XBTs can reach 700 m depth but not all, besides, upper 400 m ocean can contain the thermocline process, so we

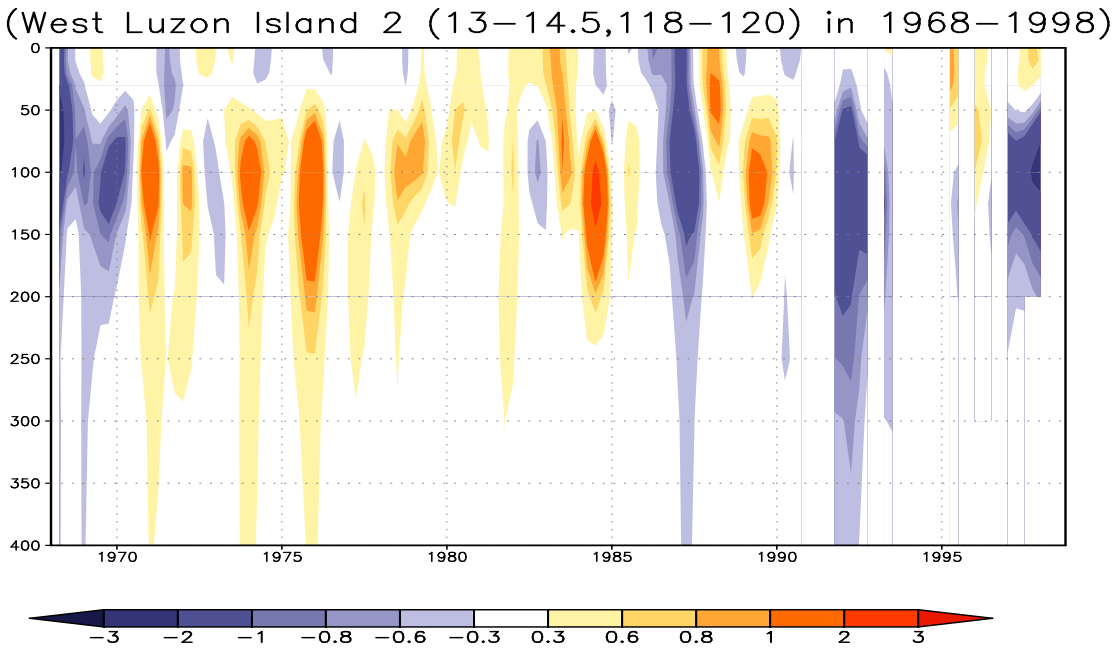
choose 400 m's heat content as the study subject. The thermocline in the South China Sea locates in the 150-250 m depth.

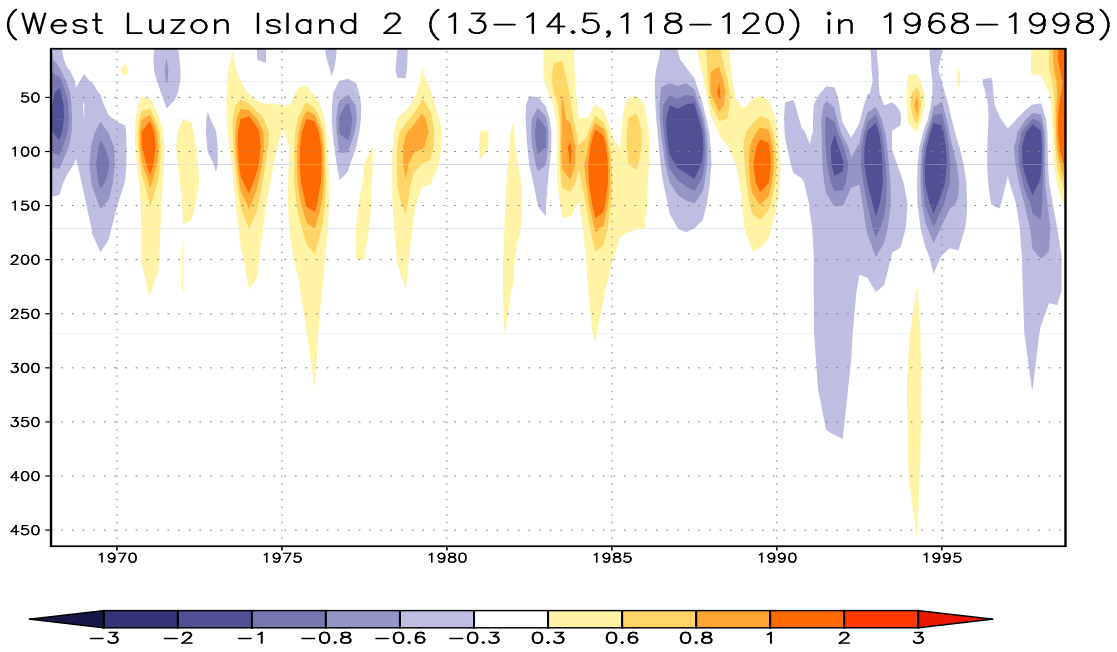
Also it says that the "climatological[ly] seasonal cycle is removed". The authors need to state how this was done, as there are good and bad ways of doing this.

- Removing the seasonal cycle means every month in the time series minus the mean of corresponding moth. For example, the anomaly in Jan1958 is the HC minus the average of all January from 1958 to 2007, we will add this description into the article.

On p1333, line 3 etc, a comparison between the XBT data and the SODA reanalysis is described. If SODA contains the XBT data, then this is superfluous, otherwise more detail needs to be show, including a map to show where the 9 boxes were and diagrams to show how well the heat contents compare.

- The SODA has assimilated most available observation including XBT, so the comparison between the XBT data and the SODA reanalysis is similar. Here we give an example:





Temperature anomaly (top: XBT, bottom: SODA), seasonal cycle removed, units: ºC;

On p1334, lines 5-7, presumably what the authors mean is that the heat content increase from 1992 to 2003 was more than twice the heat content loss from 1982 to 1992.

- It may be an inaccurate expression, what we want to say is that the

heat content increase from 1992 to 2003 is quite notable. The 'twice' is a misleading word.

We will modify the statement.

When discussing the spatial differences on p1334 the features described should be quantified.

- We do want to quantify the features and already did, but the result is bad, we thought there may be some reasons: first, the resolution of the NCEP flux is low, specific to the boxes we choose, there are only 5-7 values of the net heat flux, this may affect the quantization accuracy. Second, in the heat balance equation, the residual heat flux (including vertical advection, diffusion, etc) has the same scale with the others, whether the R is Positive or negative, it will lead to the time series of HCC, ADV and QNET mismatching. This may connect with the last comment.

In order to explain their interesting finding the authors should consider changes in the atmospheric circulation as a possible explanation for the result.

- Thanks for your suggestion. The atmospheric circulation may be a

explanation of the decadal heat content change.

p1332„ ll 3-4: “below” and “above” should be written “deeper than” and “shallower than” to be completely unambiguous.

- It is corrected.

p1332, l 25: “...likely to be related to...”

- It is corrected.

p1333, l 11: “...studying the heat budget...”

- It is corrected.

p1333, l 26: “variance” should probably be “change”.

- It is corrected.

p1338, Table 1: Does HCC = QNET + ADV + R? Please include this. Is there any idea what the errors in these numbers are?

- As the description above, the equation is indeed the 'HCC = QNET + ADV + R ', these numbers are calculated after time filtering which may cause energy loss. The energy loss includes the time-independent high frequency energy and time-dependent energy, but the low- frequency energy is a small part of the time-dependent energy.

p1340, Fig.2: The correct unit for temperature differences, temperature changes and anomalies is K.

- It is corrected.

The bottom panel is presumably heat content (and not heat content change, p1333, line 10).

- The OHC represents ocean heat content not the ocean heat content change. We have already give the abbreviation in the beginning of the article.

The text (p1333) line 5 says it is an example, line 10 says it is the South

China Sea. What are the units? To what is the anomaly relative? Any arbitrary reference level? The long term mean? If it is a restricted area, then where?

- This is the whole South China Sea, we choose the whole SCS as a box.

  We missed the unit, it is 10^{23}J.

  The anomaly relates to the climatological mean.

P1342, Fig.4: What are the units? The same scale for each panel and a zero-line would help.

- The unit is TW (1TW=10^{12}W), the figure has been redrew and the same scale and zero-line has been added.