Ocean Sci. Discuss., 11, C825–C831, 2014
www.ocean-sci-discuss.net/11/C825/2014/

Ocean Science
Discussions
Open Access

Interactive comment on "Influence of frontal cyclones evolution on the 2009 (Ekman) and 2010 (Franklin) Loop Current Eddy detachment events" *by* Y. S. Androulidakis et al.

Y. S. Androulidakis et al.

iandroul@civil.auth.gr

Received and published: 23 September 2014

General Remarks

We would like to thank Referee #1 for the useful comments and for finding our manuscript well written, rigorous and novel in the understanding of the growth of the CB frontal eddy. We have accommodated his/her comments and suggestions and we believe that the new version addresses all concerns.

Revision Points

1) It is unclear what data Gom_HYCOM is assimilating and at which frequency. Page

1954 Line 25 -> 19545 line 5) it says it assimilates all NRT data + in-situ data from DWH. While in Page 1956 line 9 "it is noted that these data are not assimilated in the model , or Page 1958 Line 21 it says that "these altimetry data are also not assimilated", suggesting that neither the in-situ nor the altimetry are assimilated.

Answer: We apologize for the confusion. In Page 1954-1955, we mention that the model assimilates near-real time data. We will now clarify that these are daily updates. We will also expand on our description on which data are assimilated and which are not (in which case they are suitable for our analysis). In addition to routine fields of near-real time satellite data, year 2010 was enriched with data associated with the monitoring of the DWH oil spill; these were assimilated. However, data from the Loop Current buoy program were not assimilated (as not available in real-time during the simulation); therefore, this is a suitable data set for our model-independent analyses. We will note that the buoy program is independent from the monitoring of the Deepwater Horizon accident, it started in 2009 and it was not designed to report in real-time. We have already noted that this valuable data set was kindly provided to us by P. Hamilton (Science Applications International Corporation; SAIC) and A. Lugo-Fernández (Bureau of Ocean Energy Management; BOEM). We also agree that the mention of AVISO 2D mapped SSH data as not being assimilated can be misleading. We will include the following clarification. The GoM-HYOM model (as OGCMs generally do) assimilates along-track altimetric, and not the AVISO mapped data. The AVISO SSH maps are projected from the original along-track data. The assimilated SSH and AVISO maps are thus not the same product. Of course, since along-track altimetry is assimilated, one expects common features with AVISO maps, but not necessarily a perfect match, as the interpolation that leads to AVISO SSH maps also makes hypothesis on the data and might degrade part of the information. Therefore, we have two altimetric data sets, one that is assimilated (along track) and one that can be used for analyses (AVISO).

2) P1957 Line 26, I guess the sharp temperature increase indicates of a transition into Loop Current Water?

Answer: Yes. As presented in Figure 5a, Loop Current was extended over the central and north Gulf covering gradually the entire grid with buoys. Eventually, around mid-June it also covered the westernmost A1 buoy and thus the temperature increased, as derived from both model and in situ timeseries (Figure 2). We thank the reviewer for this observation and we will include it in the new version of the manuscript.

3) The shape, size and orientation of the LC eddies differs between the model and AVISO ADT that is known to be an accurate and reliable data product. Even more worrying the model suggest a strong cyclonic eddy (24 N,90 W) in Figure 3a, which is not visible in the data product. This is expected if the model does not assimilate altimetry data. It is correct that the model has some skill and is skillful enough to investigate the role of the CB upwelling in the Frontal eddy growth but AVISO product seems a wiser choice to track frontal eddies and timing of eddy shedding (Figure 5) . It may be interesting to add the Global T,S,U,V,H Armor-3D L4 in the in situ comparison. Overall I find that the model validation is distracting the reader from the main objective of the paper which is to investigates the role of frontal eddy in the shedding of two warm core eddies. (All this is only suggestions).

Answer: We thank the reviewer for the suggestions. We used the AVISO maps to show the shedding of the LCE and the positions of the related north and south LCFEs at characteristic dates of the two study events. The model results agree with the satellite maps with respect to the position of the LCE, the LC body and the two LCFEs that contributed to the LCE shedding process. We agree that the AVISO ADT map shows a cyclonic eddy at (24°N, 90°W) that is not present in the model outputs. However, this eddy is not as large and intense as the three main cyclones that surround the detached LCE at the time, which are well represented in the model. Moreover, that secondary eddy did not participate in the shedding processes and therefore does not affect the main discussion and focus of the study. Again, we will clarify which altimetric data are assimilated and which ones are not in the revised manuscript. We believe that model evaluation is an important aspect of the study and it is adequate, without including an

additional dataset to compare the model outputs with. We note that: a) we show comparison with in situ data (Figure 2), b) the performance of GOM-HYCOM was tested in many previous studies and c) the satellite maps offer qualitative (but targeted) support on the good performance of the model during the two specific shedding periods.

4) There are redundancy between Section 4.1 4.2 4.3 and 5.1 making the paper hard to follow. Maybe it would be good to organize the paper w.r.t to the two eddies shedding and put less focus on the model validation.

Answer: We will follow the Reviewer's suggestion to modify the structure. Currently, section 4.1 is dedicated to the evaluation of the model during the two shedding events (summer of 2009 and summer of 2010). The Loop Current evolution is presented in Section 4.2 in order to describe the shedding events under investigation. The tracks of the cyclonic eddies during these shedding events are presented in Section 4.3. The model validation is only presented in the first section (4.1) of the results. We agree with the reviewer that the focus of the paper is the two eddy shedding events and the evolution and contribution of the cyclones to these events (Section 5). In order to separate the validation of the model from the main scope of the study, we will separate Section 4.1 from the Results Section and produce a new small section dedicated to the model evaluation during the two events (4. Model evaluation during LCE Ekman and LCE Franklin shedding sequences). According to Anonymous Referee #2, we will merge Results and Discussion sections in one single section entitle "5. Results and Discussion", including "5.1 Loop Current evolution in summers of 2009 and 2010", "5.2 LCFE tracks during Eddy Ekman and Eddy Franklin events", "5.3 Northern GoM LCFE structure and migration" and "5.4 Campeche Bank LCFE evolution and growth".

5) The part about the contribution of the CB upwelling in the formation of the CB eddy is very interesting, but one mechanism remains unclear to me. Is the upwelling "creating" PV, which then takes about 7 days to reach the Yucatan Current or is PV already presents over the bank and upwelling causes the flushing ?

Answer: This is an interesting point raised by the reviewer. Figure 15 shows that the simplified Layer 2, in which the PV anomaly associated with the CB eddy is located, is much thinner over the CB than in deeper parts of the GoM. Based on the definition of PV (Equation A1), this implies that the PV in this layer is larger over the CB than in the deep GoM. As such, the CB forms a high PV reservoir, which can be “flushed” by the offshore current following the upwelling, as suggested by the reviewer. However, diabatic processes may modify the layer PV, especially bottom friction, wind stress and mixing, which will affect the current velocity and layer thickness on the CB. Analyzing the combined effect of the processes at work is far from trivial (see for example the study by Rossi et al., 2010, on the formation of secondary upwellings). The exact role of these processes on the PV budget over the CB would require the implementation of simplified or idealistic simulations, which is beyond the scope of this study. Our goal here is to show that across-shelf exchanges can participate in the growth of meso-scale Loop Current frontal eddies. A detailed analysis of the processes at work should be the subject of future studies. However, the role of the CB as a natural high PV reservoir appears important here, and the text will be modified to include this idea. Rossi, V., Y. Morel, V. Garcon (2010). Effect of the wind on the shelf dynamics: formation of a secondary upwelling along the continental margin. Ocean Modelling. doi:10.1016/j.ocemod.2009.10.002.

6) I do not understand how layer 1 vanishes (is masked) over the Campeche Bank while layer 2 is not masked. Could it be that PV is masked because it is above the range of the colorbar ?

Answer: We will clarify in the figure caption why Layer 1 “vanishes”. The layer status is controlled by the definition of density ranges per layer that we have employed for our analysis. The simplified layers in which the PV is estimated are isopycnal, with each layer defined by a range of water density. The surface layer is associated with lighter waters. On the CB, the upwelling is associated with colder surface waters than elsewhere at the surface of the GoM, the density of which can become out of range of

the Layer 1 definition. This is what we mean when writing that Layer 1 vanishes. In that case Layer 2 is at the surface.

7) It seems also to be some inconsistency between Figure 15 and Figure 11-12: Layer 1 is not masked over the CB in Figure 15. Value seems larger than in Figure 11. (It is hard to tell because colorbar are not comparable, but PV layer 1 seems larger than in layer 2 ?)

Answer: On Figure 15 Layer 1 actually vanishes close to the shelf edge on 3 July, which is more clearly seen on the temperature section (bottom left). It is not so clear for 14 July on Figure 15, but Layer 1 actually vanishes around 87° along the section seen on Figure 15a, in agreement with Figure 11. As for the PV values, it is true that the PV in Layer 1 is larger than in Layer 2. As mentioned in the text, the CB eddy is identified based on a consistent, well-defined PV anomaly in the water column, which in this case is located in Layer 2. Although Layer 1 PV is larger, there is no such well-defined PV anomaly in that layer, compared to Layer 2. This is why the colorbar on Figure 15 is adapted to show the values of PV in that layer. The values there are consistent with Figure 12, with high PV values within the CB eddy typically reaching 0.07-0.08 *10-5 s-1.m-1.

8) Is potential vorticity analysis meaningful for layer one when HYCOM is not isopycnal and thus PV not conserved ?

Answer: Since Hycom is not isopycnal in the upper ocean, we had to first interpolate the simulation fields onto purely isopycnal layers, before grouping these ispocynal layers together into three simplified layers, which are then isopycnal by construction. This is explained in the Appendix. As mentioned by the reviewer, such an interpolation on ispoycnal layers is necessary for analyzing the eddy formation process based on PV conservation. Unfortunately, the interpolation of Hycom fields onto purely isopycnal fields leads to loss of information and errors. As mentioned in the Appendix, these errors are larger in areas shallower than 100m, but in deeper areas the interpolation can be considered valid. In particular, the processes taking place at the edge of the CB and in the deep GoM are well represented.

9) The major growth of the PV blob in Layer 2 (between 31/05-> 30/06), occurs while contribution of PV from the Campeche Bank is minimal, which suggesting that CB contribution is not critical in triggering the formation of the CB eddy. On the other end, Figure 13d and 13-e highly correlate suggesting that contribution from the Yucatan Channel (YC) is constant? It would be interesting to show the contribution from the YC.

Answer: It is true that the period between 31 May and 30 June shows the most noticeable spatial extension of the PV anomaly associated with the CB eddy. However, export of high PV from the CB toward the CB slope is visible since mid-May, which might also contribute to the CB eddy growth. Nonetheless, we agree that the contribution of the CB itself is not dominant in providing large PV to the CB eddy, since the portion of the positive PV flux toward the area of the eddy coming from the CB in Layer 2 is 38% at its maximum value. This is mentioned in the results part of the manuscript (Part 5.2.2). Although its contribution is not dominant, our analysis showed that the CB participates in the eddy growth, which is a new result. During the study period, the PV transport from the Yucatan Channel is not exactly constant, but its variations are weaker than those in the transport from the CB, which is why the time series on Figure 13e and 13d look quite similar. We find that Figure 13 is already quite dense, and that adding the time series of the PV transport from the Yucatan Channel, which shows little variations, would not bring additional valuable information; this is why we prefer to keep Figure 13 as it is.

Interactive comment on Ocean Sci. Discuss., 11, 1949, 2014.