Thanks for the valuable comments from Referee #1. We carefully studied these helpful comments, and hope the following responses could meet with referee's approval. The manuscript will be further adapted according to these comments after the discussion is closed.

1. "… taking second derivative of SSHA data … is the weak part of the method"

To address the excessive detection problem of OW method, our method added an extra criterion that the eddy area OW criterion ($W<-0.2\delta$) abstracted should cover at least a SLA local minimum/maximum. Can this additional criterion really improve the detection accuracy, or is it the weakness of the method?

First, we studied the adapted WA method in Chaigneau et al.(2008), and found that using SLA local extrema to locate eddies is the key point of their method, and the validation results in their publication proved method's better performances over OW method. So, we came up an idea of combining the OW criterion and SLA extrema criterion.

Second, in our study, we adopted the same objective validation in Chaigneau et al.(2008) to evaluate method's performance, and the results suggest that HD method is better than OW method and the adapted WA method.

So, we believe the adding criterion is an improvement. It helps minimize the over-detection problem of OW method.

2. “the manuscript fails to provide any definition or adopt any definition on these important concepts (how to define an eddy, and how to define an eddy boundary)”.

We agree with the referee on the two challenging problems of eddy detection. And we are sorry for not explicitly providing the definition of an eddy and its boundary in the manuscript.

First, the HD method we proposed is an integration of OW criterion and SLA extrema criterion. So both the definitions of the two methods concerning the “eddy” were adopted.

Eddy definition of OW method:

“Hunt et al.(1988) defined eddy cores as regions in which the second invariant of the velocity gradient tensor is positive and the pressure tends to a minimum.”(Isern-Fontanet et al. 2003)

Eddy definition of WA method:

“A vortex exists when instantaneous streamlines mapped onto a plane normal to the vortex core exhibit a roughly circular or spiral pattern”(Robinson 1991)

Second, for the definition of an eddy boundary, we agree that “a universal definition of eddy boundaries does not exist, each method is equally acceptable, as long as its criteria are very precisely specified and the results are tested” (Nencioli et al. 2010). Our method defines that the minimum closed SLA contour that covers the eddy’s core area is regarded as the qualified boundary (P7, L26-27). Using this definition, we can

definitely determine the eddies' boundaries. And Figure 6 in manuscript shows the abstraction results and differences with the expert's and other methods'.

3.the experts' result in detection validation

Yes, we cannot absolutely avoid the subjective bias of human in the validation. But in current studies, we believe this validation approach, Chaigneau et al.(2008) also used, is at least an acceptable way to evaluate method's accuracy. In Chaigneau et al.(2008), they invited five experts to do the manual detection on ten samples. About 20% of the eddies are identified by only one or two experts. In our study, we adopted the same procedure and performed the validation. The inconsistent rate of expert is about 20.7%, almost the same as Chaigneau et al.'s result. So, we believe the expert results in our study are meaningful, at least the manual detection were as efficient as those in Chaigneau et al.(2008).

4. "Most comments on the existing algorithm presented in this manuscript lack substantial and convincing arguments. Some comments are only subjective. The comparison part among different methods is not well justified. The manuscript should credit authors who provided source codes of different methods for the comparison."

Yes, we are so sorry for not crediting the detection results provider and source codes provider. The detection result of WA method is kindly provided by A. Chaigneau. And the VG result is produced by the code provided by Nencioli et al. The OW

method and SSH method are implemented in this study according to their description in literature, and the detection results are produced by the program. We particularly thank them for sharing their researches, and will credit them in the manuscript.

As for the method comparison, we hoped to make a substantial and quantitative comparison between different detection methods. But method like WA does not provide the source code. We only have the detection result on that date in the ESP. So, we can only visually presented each method's detection differences on that date and intended not to conclude which is the best. We also calculated the EDR and SDR to evaluate the methods in this single test to make a quantitative comparison. And the result showed HD method, though is not the best, is able to recognize multi-core structures, and the performance was the second best.

5. the method's limitation

Yes, we will discuss HD's limitation in the manuscript. One major limitation is that whether the criteria for recognizing the multi-core structures are proper and whether they can real reflect eddies' mutual interactions require further studies. However, current studies about eddies' interaction and the definition composite structure are few. Validation remains challenging. But to support the detection and tracking eddies' composite structure we believe is a big improvement of automated methods.