Response to the reviewer comments

The Authors thank the reviewer for their comments that have helped to improve our manuscript. We hope that the reviewer finds our manuscript now suitable for publication in Ocean Science. Hereinafter, the reviewer's comments are in black and the authors' answers in blue.

General comment:

This paper proposed a new method for determining the upper and lower bounds of the thermocline. The method applies the sigmoid function to fit the Argo temperature profiles, then locates the mixed layer depth (MLD) and maximum thermocline depth (MTD) by using a temperature threshold (0.2â). The authors provided convincing evidence that the new method can determine similar MLD as the other two widely used methods (HT09 and B04). Next, they presented the global climatology of thermocline thickness and characterized their distribution patterns. The method is easy to conduct, and the MLD and MTD can be calculated as promised in the paper, although some details need to be reconsidered. The paper is well organized with a clear presentation, and I believe the new method is of great value to the readers and will help oceanographers who are interested in calculating MTD, after some adjustments.

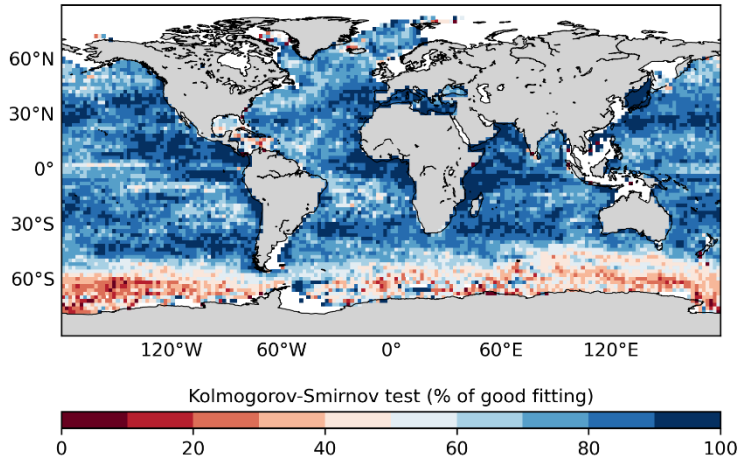
Major comment:

The authors used R2 as the criterion for the goodness of fitting, while R2 values can be high even if the fitting functions don't fit the data well.

We thank the reviewer for bringing this up as the evaluation of the errors in the fitting is a subject that we have taken very seriously in our study. We have made an extensive bibliographic revision in order to decide which was the best method to estimate the goodness of the sigmoid fit. We found that numerous scientific studies from various areas use R^2 to evaluate the goodness of fit in sigmoid functions (e.g., Cao et al., 2019; Bhogal et al., 2014; Ritz and Spiess, 2008; Liu and Saint, 2002; Van der Graaf and Schoemaker, 1999). We have added these references (lines 293-295) in the new version of the manuscript.

Despite the generalized use of the R^2 method, we also analyzed its adequacy in our particular case of study in comparison with other methods. In our methodology is critical to adjust the diagonal part of the sigmoid to the thermocline and the upper straight line to the mixed layer. The lower straight line is meant to represent the deep layer, but its variations are not critical for our method to be accurate. In Figure 1e and f of the manuscript, it can be seen how the variations of the deep layer do not follow the straight line of the sigmoid, however, this is not the aim of the adjustment, and it does not compromise the validity of our results as it can be deduced from Figure 1.

We have calculated other goodness-of-fit measures (not shown in the manuscript) to validate the method, however, due to the situation described above (variations in the deep layer), we decided not to include them. The figure shown below shows the percentage of good fitting of the temperature profiles to the sigmoid function in a 2°x2° grid calculated with the Kolmogorov–Smirnov test.



This test compares the distribution of a sample (temperature profile) with a given distribution (the sigmoid). As can be seen in the figure, this test shows a good fit in most ocean profiles (blue cells), but this test fails when the temperature profile shows variations in the deep layer, even if the method locates correctly the thermocline, as is the case with the profiles in Figure 1e and f of the manuscript. Despite this, the results obtained with both tests (Kolmogorov–Smirnov and R^2) are consistent and there is no test that is universally valid, as can be seen in the variety of tests used in the literature.

So in addition to R^2, the study provides other validations of our method: (ii) the averaged relative contribution of temperature and salinity at the most stratified point of the ocean water column (Figure 2), (ii) the comparisons of three different methodologies to locate the MLD (Figure 6), and (iii) the localization of the thermocline in temperature profiles with the proposed method and the VRI method (Figure S2 in the Supplementary information). We believe that with all this information clearly presented in our manuscript we compensate the possible limitations of R^2 and more importantly, we clearly show to the readers the limitations of out method.

The examples shown in Figure 1 in the manuscript are all partial profiles, which can be misleading because it is unknown to the readers whether the thermoclines are fully included. Also, in Figure 1 the thermoclines are all thin, less than 100 m. When it comes to thick thermoclines, such as shown in the figure of the supplement file, the thermocline lies between ~50 m to ~400 m, and it is possible that the depth of twice the maximum N2 doesn't cover the thermocline. The deep layer is not captured by the fitting in the supplement figure, and thus the MTD result is much shallower than the actual one. However, if the upper 500 m profile is used to perform the fitting, the upper mixed layer can not be well captured (figure not shown). The fitting depth range should be reconsidered to better present the features of temperature profiles.

We than the reviewer for pointing this out. We think that the reviewer is right as we agree that this was not clear in the manuscript. In this new version of the manuscript, we have specified that our method, by using the most stratified point of the water column, locates the strongest thermocline which in most cases will coincide with the seasonal one, and sometimes will coincide with the permanent thermocline shown in the reviewer's example (lines 3, 240, 245-247 and 319) and we believe that this precision of out method is we have corrected it.

The examples in Figure 1 are intentionally shown as partial profiles to make it easier for the reader to understand the fit of the sigmoid function to the temperature profile by using the most stratified point. These same profiles are shown up to 2000 m depth in Figure S2 of the Supplementary information, where they showed better results than the best method consulted in the background. We have now added this to the manuscript in case the reader wants to see the full profiles (line 116).

Minor comment:

Line 1: "… divided into three layers: the mixed layer …"

Mistake corrected (line 2).

Line 34: "plays a key role …"

In this sentence we are speaking in the plural, referring to the MLD, the MTD and the strength of the thermocline. We rewrote the sentence hoping it will be clearer (lines 33-35): "The Mixed Layer Depth (MLD), which is also the top of the thermocline; as well as the Maximum Thermocline Depth (MTD), and thermocline strength, all play a key role in…"

Line 51: "Previous regional studies have identified a shallowing and strengthening thermocline in …"

Mistake corrected (line 52).

Line 59: the meaning of MTD is not given.

Mistake corrected (lines 34).

Line 214: "…500 m in the core …"

Mistake corrected (line 216).

Line 239: "… three main layers: the mixed layer …"

Mistake corrected (lines 242).

Line 283-284: "and only gave good results with profiles located in tropical latitudes" is repeated twice.

Mistake corrected (lines 288-289).

Line 313: "… minimum and maximum depths of …"

Mistake corrected (line 319).