Dear editors,

All comments have been answered in the public discussion, and author's changes in manuscript are as follows, more details are showing in the marked-up manuscript.

1. The word “and” between authors’ name is removed.
2. The word “section”(page 3, line 5) is replaced by ”stage” as suggested by Referee #1.
3. In page 4, line 27, one sentence is added to explain the first question of Referee #2 which is about the threshold(1%), and a numerical experiment is added to test the threshold as shown in “author's response to referees 2”.
4. According to Referee #2 suggestion, some explanations in terms of climate systems are added in section 3.1(page 6, line 1)
5. Two references are added in the manuscript(page 11, line 13; page 11, line28)
6. Figure1 is replaced by an improved edition(page 12, line 14)
7. Some other changes are showing in the marked-up manuscript (Supplement) clearly.

Reply to Referee #1

Dear Referee,

We appreciate your interest to our article and your comments. We reply on the comments as follows:

(1) **Referee.** In figure 4, the abrupt changes occurred in different locations of the oceans at the same time. Please discuss possible mechanism about them. Are there some teleconnections between them or just a casual one?

Authors. Actually, it is a question about the standard of the abrupt change. In present manuscript, the method is based on the percentile threshold method, and this is a relatively standard. Thus, when an abrupt change in one grid is detected, it means that the difference between the two states before and after the abrupt change of this moment has the biggest amplitude by comparing with the other moment. Taking fig. A3 for example, we know that both the two series have two abrupt changes in moment t1 and t2 respectively. However, when we detect the abrupt change by setting a standard, only one abrupt change can be considered as a real abrupt change. The amplitude of the abrupt change should be bigger than any others. Then, it is in moment t1 for grid 1 and it is in moment t2 for grid 2. Therefore, when the abrupt changes of different grids are detected, the abrupt change moments of two adjacent points could be different. It is inferred that the longer the time sequence, the more disperse the abrupt change space will be.

There could be some teleconnections between the abrupt changes occurring in different locations at the same time, because they are likely to be driven by the same force. It's complex and difficult to explain the mechanism. Before that, it has to dig out how the different standard effect on the detection of abrupt change. When all the real abrupt changes are obtained, it is easy to know how the abrupt change transforming from one place to another in dynamics. However, in present manuscript, we just did some basic research about the transition process, proposing a special quantitative relationship. The relationship will be used to study the physical mechanism of abrupt change by climate model.

(2) **Referee.** Since the parameter χ is a function of α and β, χ becomes a constant if set α=0.2, β=0.8. Why?

Authors. This issue was discussed in the previous paper(Yan et al, 2015). α and β represent two points($A(X_\alpha,t_\alpha)$, $B(X_\beta,t_\beta)$) of the transition process, respectively (as shown in fig. A1), then α, $\beta\in(0,1)$. According to the function as mentioned in line 15, page 3, the location parameter χ can be expressed by α and β. As shown in fig. A2, it is found that parameter χ is almost constant when the values of α and β are within a certain range. Therefore, we think that that parameter χ is approximately constant.

(3)**Referee.** The word "and" should be removed in the author list.

Authors. We are going to correct this mistake.

(4)**Referee.** Formula (3): The word "section1, section2, section3" may be replaced by "stage 1, stage2, stage3" or "domain1, domain2, doman3"?

Authors. The words "section1, section2, section3" will be replaced by "stage 1, stage2, stage3".

Appendix：

Figures

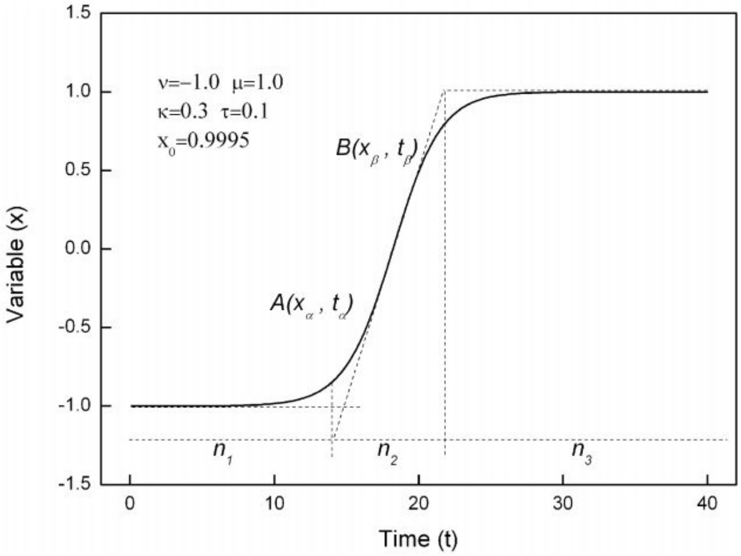

Fig. A1. The transition process of abrupt change with two points. (according to reference [1])

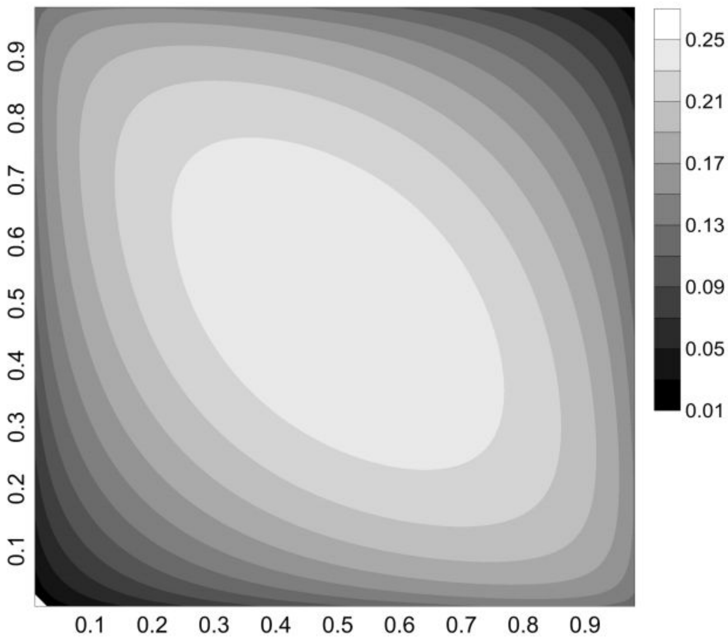

Fig. A2. The relationship parameter χ and parameters α, β, where the x axis is parameter α, the y axis is parameter β and the contour is parameter χ. (according to reference [1])

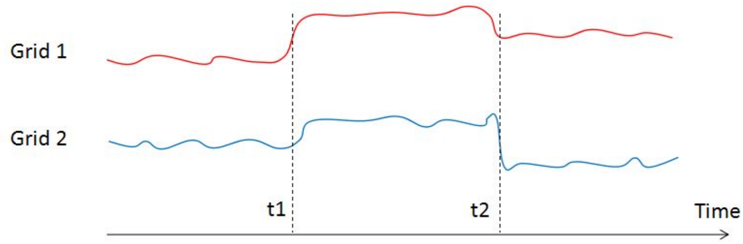

Fig. A3. To detect the abrupt change of different grids.

Reference

[1] Yan P. C., Feng G. .L, Hou W., 2015: A novel method for analyzing the process of abrupt climate change. Nonlin. Processes Geophys. 22, 249–258, doi,10.5194/npg-22-249-2015

Reply to Referee #2

Dear Referee,

We appreciate your interest to our article. As your noticed, the method was published in this same journal, and this manuscript is a following work. In the previous paper, a novel method was proposed and applied to the Pacific Decadal Oscillation index. It's true that the index states "a system that are continually changing its behaviour between positive and negative states". By applying the detection method, several abrupt changes were verified. In reference [1, appendix], this method was used to study the transition process of 500 hPa temperature field. That result exposed a new statistical characteristics of the abrupt climate change.

And for the comments, we reply on them as follows:

1. Referee. PDO index synthesize the collective behaviour of an extended area of the ocean.But having a great number of series varying we can randomly detect a possible abrupt climate change that is not real in a single point of the ocean. To avoid this possibility authors put a threshold of 1% of the points performing this abrupt changes. Nevertheless the value of SST of one grid square is not independent of the value of the SST of neighbouring grid squares. Therefore I suggest to made an interdependence test to calculate this threshold. This can be done by replacing SST series with a Gaussian noise series generated from a normal population whose mean and variance are identical to that of the series over the whole studied period, examining abrupt changes in these series and repeating the process a number of times equal to the number of grid points. In this way the number of abrupt changes can diminish and the results could be more representative of real abrupt changes.

Authors. In figure 1(appendix), a brief sketch map shows how to verify the abrupt change with the percentile threshold method. When the blue box moves to moment i, a start moment(red point) of the abrupt change is verified by fitting the sub-sequence with the piece function(as introduced in the manuscript). Then, by moving the blue box to moment i+1, the same point is identified as the start moment. When the blue box moves on the entire time sequence, a series of start moments would be detected. It's noticed that the amplitudes are obtained when the start moments are identified. Through the percentile threshold method, as shown in right figure, the amplitudes with high value(more than the confidence level) is believed as the real abrupt change. Then the start moment of the abrupt change of this series can be obtained. In figure 1(manuscript), the frequency of all grids' start moments and end moments were shown. When the standard is set as 1%, it means that abrupt change occurs in more than 1% of all global grids at that moment. Apparently, when the standard is set as 2% or more, abrupt changes of some moments will not be displayed for studying in this manuscript, but it would not be diminished. In this manuscript, we set the standard as 1% to study several abrupt changes and demonstrate the quantitative relationship of the transition process.

A numerical experiment was taken to test the method as shown in figure 2(appendix). Two ideal time series and their frequencies of the amplitude are shown. All amplitude's value are less than the confidence level(2.05), which indicates that there are no abrupt changes for the time series. For each gird time series, the number of abrupt changes is supplemented(supplementary documents), and they are different from each other.

2. Referee. Once performed the point 1 it is possible that the number of abrupt changes diminishes. In any case I suggest to the authors to made the effort to give an explanation of the patterns in terms of climate systems. Thus for example in figure 1 the changes detected in 1976 and 1982 are related to ENSO area. The change of 1976 is a well documented phenomenon called climate shift. In 1982 one of the most important ENSO episodes took place.

Authors. Actually, as discussed in question 1, the number of abrupt changes won't be diminished.

3. Referee. As a minor question I also suggest to carefully read the paper because there are some important mistakes.

Authors. The authors thank the anonymous Referee #2, and the mistakes will be corrected.

Appendix：

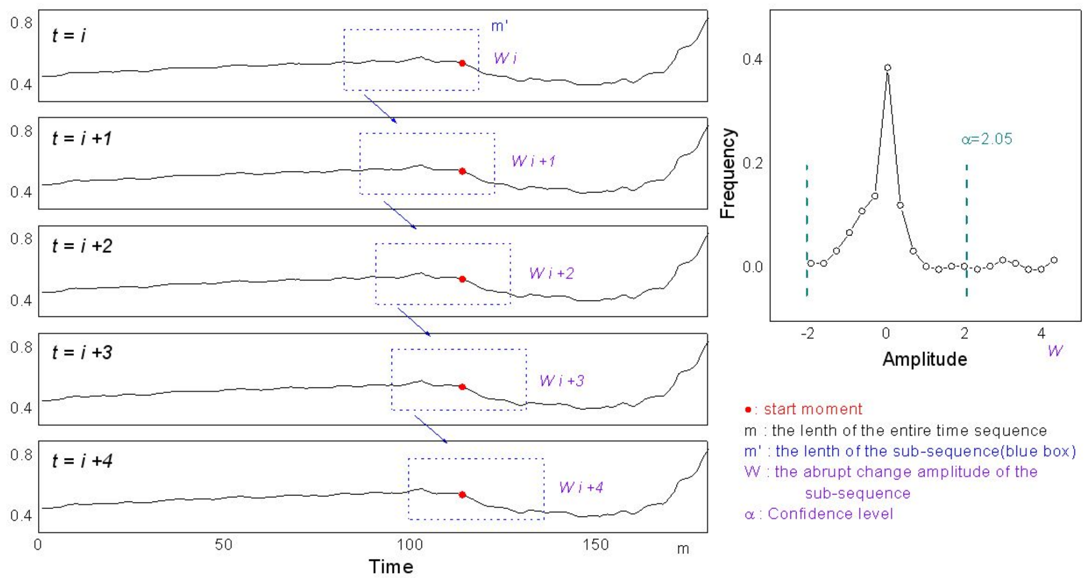

Fig.1. For each time series, a brief sketch map to tell how to verify the abrupt change with the percentile threshold method.

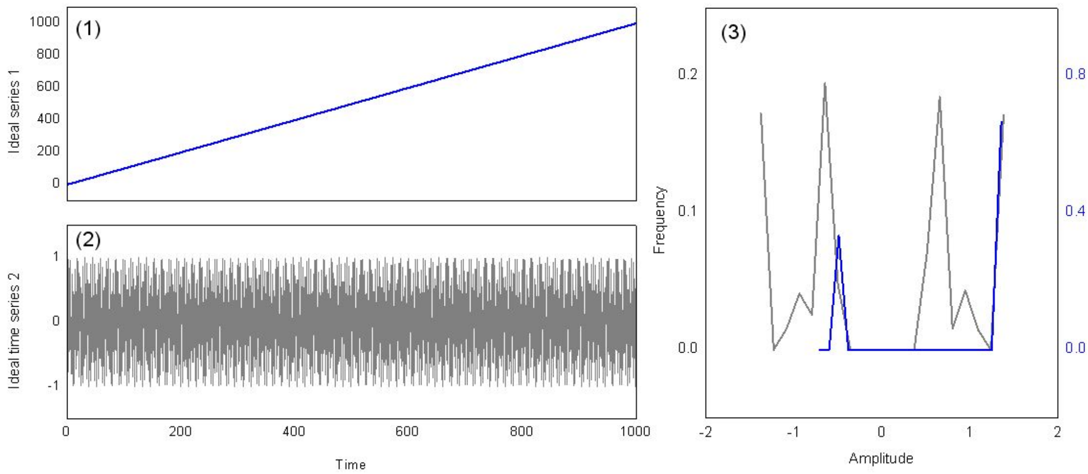

Fig.2. Two ideal time series and their frequencies of amplitude.

Reference

[1]Yan Pengcheng, Feng Guolin, Hou Wei, et al. 2014. Statistical characteristics on decadal abrupt change process of time sequence in 500 hPa temperature field [J]. Chinese Journal of Atmospheric Sciences (in Chinese), 38 (5): 861−873.