Responses to Reviewer #1:

Comments and suggestions:

This paper mainly addresses three key points: (1) the surface temperature-warming rate of TP area is greater than the rate of global warming; (2) the temperature change is related with elevation; (3) the TP warming is one of the factors which influence the East Asian summer monsoon. Linear regression analysis and Mann-Kendal trend test are adopted. Overall, the statistical methods used in this paper are not rigorous. For instance, the linear regression used in this paper does not provide the assessment of goodness of fit or validation. With this problem, all of the diagnosis which based on the regression are not acceptable. So, I would not recommend this paper unless the authors significantly improve their study.

Response: We appreciate the reviewer's valuable comments that allowed us to improve the manuscript substantially. We have carefully considered these comments and revised the manuscript.

To check whether the trend is reliable or not, Mann-Kendall (M-K) trend test and Theil-Sen estimator are both used. Kolmogorov-Smirnov test is applied to check the statistical significance of normal distribution. The significance of all the regression method and other analysis are determined by the standard two-tailed Student's t test method. This part of the content is described in detail in the method. (P2, L170-185). Please see below for our point-by-point response. The original comments are quoted in Italic.

Major Comments:

Comment 1*. Lines 134-135: "In the eastern part of the TP, stations at altitudes above 2000 m are selected as representative stations." Why stations above 2000m are selected? Why only eastern part?*

Response: Thank you for your valuable comments. Lawrimore et al. (2011) pointed out that regions above 5000 m above sea level are mostly unexplored even if stations installed at such high altitudes would be crucial to fully understand hydro-climatic processes in the mountains. After quality control, if we choose a site with elevation of 4000 meters or 3000 meters, there are only 9 or 35 stations. To get enough samples, here sites with an elevation of more than 2,000 meters are selected, and the altitude are still higher than the surrounding area, which are also representative. In the previous studies, there were also sites selected with elevation of 2000 meters. Su et al., (2017) chose the gird-averaged results above 2000m in the JRA-55 and MERRA reanalysis datasets to quantitative analysis surface warming amplification over the Tibetan Plateau after the late 1990s using surface energy balance equation. Therefore, we think it is reasonable that stations above 2000m are selected to represent TP.

All situ observation stations with elevations over 2,000 meters are provided by the China Meteorological Science Data Network are indicated in Figure S1. As is showed, a majority of the stations are located in the eastern TP (25°–40°N, 90°–110°E), only 6 stations are located outside the region. In this paper, we only selected concentrated areas to represent the TP to avoid the influence of interpolation on the TP surface temperature. The above results and analysis have been supplemented in the paper. (Figure S1, P2, L158-169)

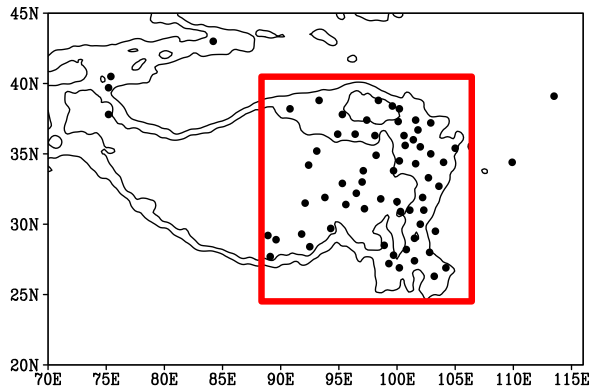

Figure S1. Situ observation stations with elevations over 2,000 meters of the daily climate dataset (version 3.0) provided by the China Meteorological Science Data Network (The contours represent altitudes of 2000 and 4000m respectively).

Reference:

Su J. Duan A. and Xu H.: Quantitative analysis of surface warming amplification over the Tibetan Plateau after the late 1990s using surface energy balance equation, Atmos. Sci. Let., DOI:

10.1002/asl.732, 2017.

Lawrimore J., Menne M., Gleason B., Williams C., Wuertz D., Vose R., Rennie J.: An overview of the global historical climatology network monthly mean temperature data set, version 3, J Geophys Res 116: D19121. doi:10.1029/2011JD016187, 2011.

Comment 2: *Line 139-146: Regression analysis and linear correlation are different, please double check the methodologies and cited literatures.*

Response: Thank you for reminding. We have removed this part of the content. Climate-land-atmosphere interact are complex systems under the influence of global warming. In addition to TP temperature, one of the important factor affected annual variability of EASM is the El Niño-Southern Oscillation (ENSO; Wu et al. 2003). On decadal scales, the influence of ENSO on the monsoon can also be strongly modulated by the Pacific Decadal Oscillation (PDO; Feng et al. 2014; Song and Zhou 2015). However, the variability of the tropical Pacific can make clear only part of the complex structure of the monsoon. Recently, remote teleconnections on East Asia from the North Atlantic region have garnered considerable attention. For example, the Atlantic Multidecadal Oscillation (AMO) has been linked to multidecadal changes in atmospheric circulation and precipitation over China (Lu et al. 2006; Lin et al. 2016; Wu et al. 2016a, b). The Western North Pacific Subtropical High (WNPSH) is an also crucial component of the EASM system and significantly influences the precipitation in East Asia (Lee et al., 2013). On the whole, global warming and interdecadal natural variability such as ENSO, NPSH, PDO, and AMO also influence the summer rainfall change in this area. The multiple linear regression is used to explain the relationship between one continuous dependent variable and two or more independent variables, and here it is applied to exclude these factors. The significance of all the regression method are determined by the standard two-tailed Student's t test method. The results are added in the revised manuscript (P1, L102-119; P2, L178-185).

Reference:

Wu R, Hu ZZ, Kirtman BP (2003) Evolution of ENSO-related rainfall anomalies in East Asia. J Clim 16:3742–3758.

Feng J, Wang L, Chen W (2014) How does the East Asian summer monsoon behave in the decaying phase of El Niño during different PDO phases? J Clim 27:2682–2698
Song F, Zhou T (2015) The Crucial role of internal variability in modulating the decadal variation of the East Asian Summer Monsoon–ENSO Relationship during the twentieth century. J Clim 28:7093–7107
Lu R, Dong B, Ding H (2006) Impact of the Atlantic Multidecadal Oscillation on the Asian summer monsoon. Geophys Res Lett 33: L24701. https://doi.org/10.1029/2006GL027655
Lin J S, Wu B, Zhou TJ (2016) Is the interdecadal circumglobal teleconnection pattern excited by the Atlantic multidecadal Oscillation? Atmos Ocean Sci Lett 9:451–457.
Wu B, Lin J, Zhou T (2016a) Interdecadal circumglobal teleconnection pattern during boreal summer. Atmos Sci Lett 17:446–452
Wu Q, Yan Y, Chen D (2016b) Seasonal prediction of East Asian monsoon precipitation: skill sensitivity to various climate variabilities. Int J Climatol 36:324–333
Lu, R., 2001: Interannual variability of the summertime North Pacific subtropical high and its relation to atmospheric convection over the Warm Pool. J. Meteor. Soc. Japan, 79, 771-783.
Sun-Seon Lee, Ye-Won Seo, Kyung-Ja Ha, and Jong-Ghap Jhun. Impact of the Western North Pacific Subtropical High on the East Asian Monsoon Precipitation and the Indian Ocean Precipitation in the Boreal Summertime. Asia-Pacific J. Atmos. Sci., 49(2), 171-182, 2013. DOI:10.1007/s13143-013-0018-x

Comment 3: *Line 157-170: Station based and region based trend analysis are done, together with some discussion on interannual variability. In fact, these results suggest that the study did not clarify which part is the trend, which part is the variability. Because the authors themselves also noticed and mentioned that "Between 1979 and 2004, the interannual variability of temperature on the TP is relatively small (except in 1981), basically remaining between 12.6°C and 14°C." Then before, the authors said "A marked increase is apparent in the past 40 years in the eastern part of the plateau, of which 56 stations show a statistically significant trend at the 95% confidence level (solid red dots). There are 16 stations with a trend exceeding 0.5°C/decade, all distributed over the northeast and southwest sides of the TP, among which Mangya Station (No.51886) even has a trend greater than 1.0°C/decade." These results made me wonder whether the trend analysis is reliable as probably there are abnormal years that affect the trend analysis, especially, trend analysis is not robust when the data is short.*

Response: Thank you for your valuable comments. There is interannual variability of temperature on the TP, especially after 2005, but a significant increase is still existed in the past 37 years. To check whether the trend is reliable or not throughout the study period, Mann-Kendall non-parametric test and Theil-Sen estimator are both used. First, Mann-Kendall method is used to test whether there is a regime shift in TP temperature, and the result is showed in Figure 2. A regime shift is found in 1997, and it is tested statistically significant at the 99% confidence level. Then the time is broken into two periods, 1980-1996 and 1997-2016, to check whether the trend is significant in different period. Both Mann-Kendall test and Theil-Sen are applied to calculating linear trend in 1980-2016, 1980-1996 and 1997-2016 (black line) respectively (Figure 3). Both methods show that the trend of the three periods is tested by a certain level of significance. So, it is believed that the trend analysis here is reliable and robust although there are abnormal years. The results and analysis above have been supplemented in the paper. (Figure 2, P3, L194-204)

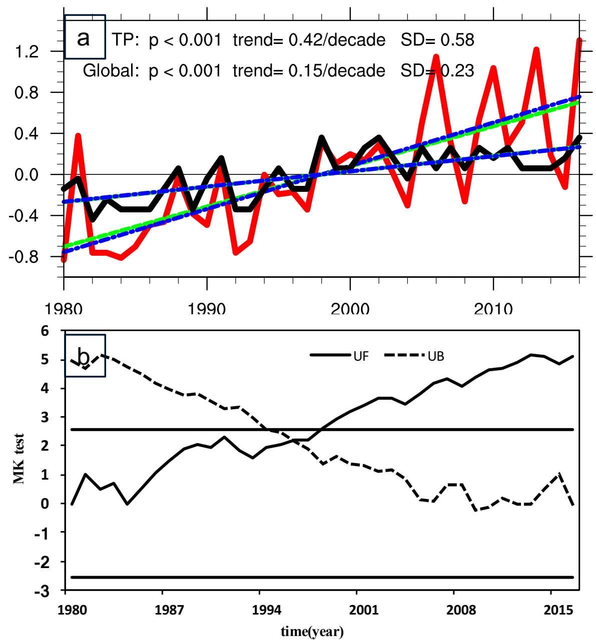

Figure 2. (a) Interannual change of summer temperature averaged by the TP (red) and global (blue). Trend significant test are from Mann-Kendall test (blue line) and the Theil-Sen estimator (green line). (Units: °C). (b) Mann-Kendall regime shift test of the temperature of the eastern part of the TP. Both are statistically significant at the 99% confidence level.

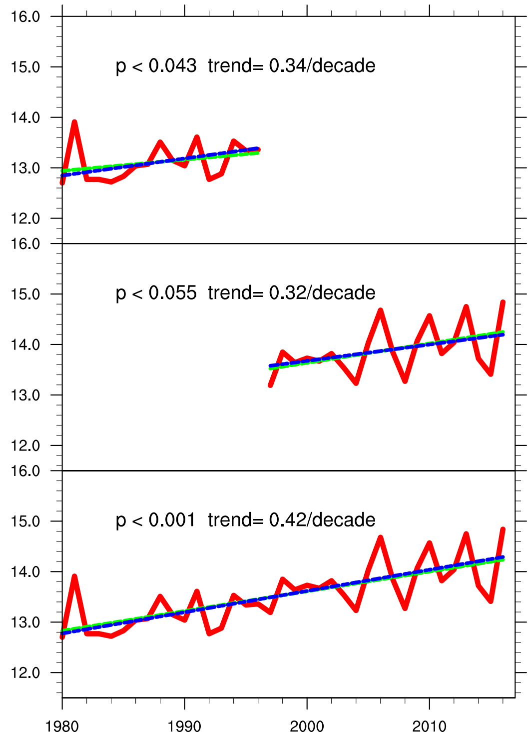

Figure S2. Trend analysis by Mann-Kendall test (red line) and the Theil-Sen estimator (blue line) for 1980-2016, 1980-1997 and 1998-2016 (black line) respectively.

Comment 4: *Line 186-190: "From the results of the two sets of data (Figure 2a and 2b), it is clear that the temperature of the TP and its surrounding areas decrease with increasing altitude, which is consistent with the variation of tropospheric temperature with height. However, it decreases at a rate of 0.43°C–0.45°C/100 meters, which is lower than the lapse rate (0.6°C/100 meters) in the tropospheric 190 atmospheres". This statement is also based on the linear regression, assessments of goodness of fit shall be added. The same problem also exists in Line 199-201 and Line 222-223 and other places.*

Response: Thanks for your suggestions.

(1) In the original manuscript, Mann-Kendall (M-K) trend test is used to check whether the trend is reliable or not. The M-K test is a non-parametric test used to detect the presence of linear or non-linear trends in time series data. So, assessments of goodness of fit are already done, and we so sorry that we should clearly point out in the text. In revised manuscript, Figure 2 of the original is arranged in Figure 3. The

red line in Figure 3 are the linear fitting curve; ** represent statistically significant above the 99% confidence level. The details that have been add as follows:

"To further analyzes elevation-dependent warming on the TP, its surrounding areas (20°–40°N, 90°–110°E; dashed frame in Figure 1) are employed, and the results are shown in Figure 3 (** in the top right corner of the picture represent statistically significant above the 99% confidence level)." (P3, L213-215)

(2) In Line 199-201, assessments of goodness of fit are also already done by using Mann-Kendall (M-K) trend test. The details that have been revised as follows:

"Figure 3c and 3d show the elevation-dependence of the warming rates. Both of them show higher elevation, higher warming rate, and linear trends are statistically significant at the 99% confidence level. "(P3, L226-228)

(3) In Line 222-223, assessments of goodness of fit are also already done. The details that have been revised as follows:

"Kolmogorov-Smirnov test is applied to check the statistical significance of normal distribution. If the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis that the sample follows a normal distribution. "(P2, L175-177).

"The statistical significance of climate mean analysis is determined by the standard two-tailed Student's t test method. "(P2, L184-185).

"As shown in Figure 4a and 4b, the normal distribution curve fit of the 2000–6000 meters temperature rate is significantly more concentrated and shifted to the right compared to that of 0–2000meters. The average temperature-change rate increases from 0.26°C/decade to 0.39°C/decade ($p<0.001$). It can be seen that, with the increase of elevation, the temperature-change rate of the TP and its surrounding areas increases significantly. There is the same phenomenon between the MERRA reanalysis data and the observational data despite difference in value. There are also significant differences between 0-2000 and 2000-4000m layers changes. The average temperature-change rate increases from 0.02°C/decade to 0.07°C/decade ($p<0.001$). Between 2000-4000 and 4000-6000m, the average temperature-change rate increases from 0.07°C/decade to 0.28°C/decade ($p<0.001$). " (P3, L244-252).

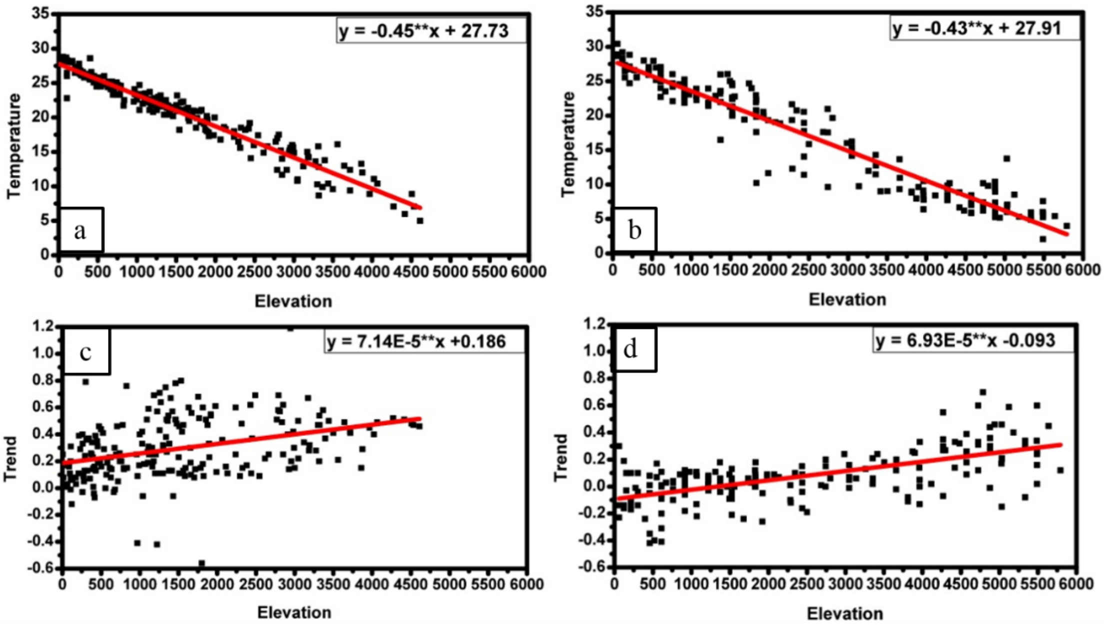

Figure 3. The (a, b) temperature (units: °C) and (c, d) temperature change rate (units: °C/decade) over the TP and its surrounding areas as a function of altitude: (a, c) observations;(b, d) MERRA2. The red line is the linear fitting curve; **, statistically significant above the 99% confidence level.

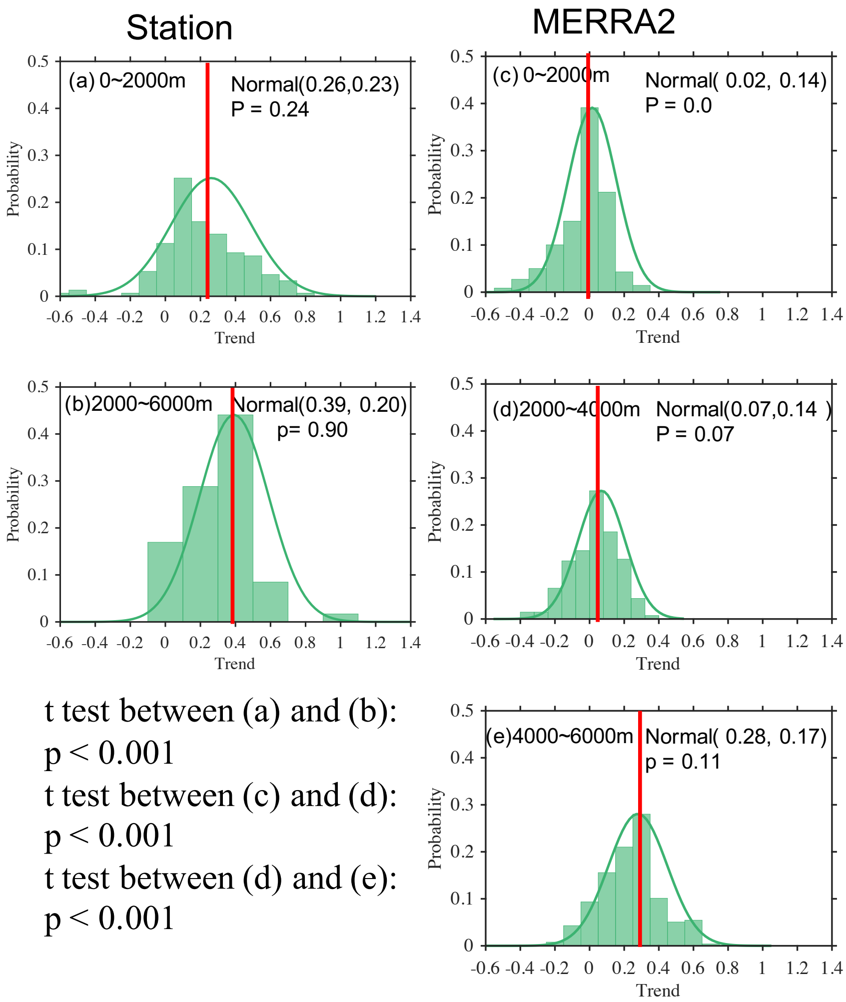

Figure 4. Distribution of probability density function of temperature trend (a, b, observational data; c, d, e, MERRA2 data; units: °C/decade) in the TP and its surrounding areas. The histogram represents the samples size, and the curve is a normal distribution fit line. The red line represents the mean of sample. The means and SDs of the normal distribution fit are also added in the upper right corner of the diagram. (a), (b) indicates the altitude ranges of 0–2000 m, and 2000–6000 m, respectively. (c), (d), (e) indicates the altitude ranges of 0–2000 m, 2000–4000 m and 4s000–6000 m, respectively. All graphs are statistically significant at the 95% confidence level by Kolmogorov-Smirnov test except (c). All mean tests are passed by student t test.

Comment 5*: Line 207: "The large-scale terrain of the TP has a magnifying effect on the warming rate of warm air, …" I could not follow the authors conclusion. This might be speculation without evidence.*

Response: Thanks for your advice, we deleted this sentence "The large-scale terrain of the TP has a magnifying effect on the warming rate of warm air, and the temperature increase in the high-altitude region is higher than that in the low-altitude region." Because we just provided a brief discussion about the temperature of the TP and its surrounding areas decreases with elevation by 0.43–0.45°C/100 meters, which is lower than the standard tropospheric lapse rate (about 0.6°C/-100 meters). This is not a strong conclusion of our work due to without the deeper explore in this manuscript. Thanks for your valuable comment again.

Comment 6: *Line 214-218: Authors divide the altitude into three and two levels based on MERRA reanalysis data and observational data. However, there is no explanation on why they did this.*

Response: Thank you for your suggests, we have added a brief discussion. In revised manuscript, Figure 3 of the original is arranged in Figure 4. "As shown in Figure 4, Elevation of stations (grids) in TP between 2000-6000 m are selected to analysis. Simply the stations are average divided into three levels, that is 0-2000m, 2000-4000m, 4000-6000. Considering that there are only few stations above 4000-6000 m, here the stations at the ranges of 2000–4000 and 4000–6000 m are merged together into 2000-6000, and the results are shown in Figure 4." (P3, L238-243)

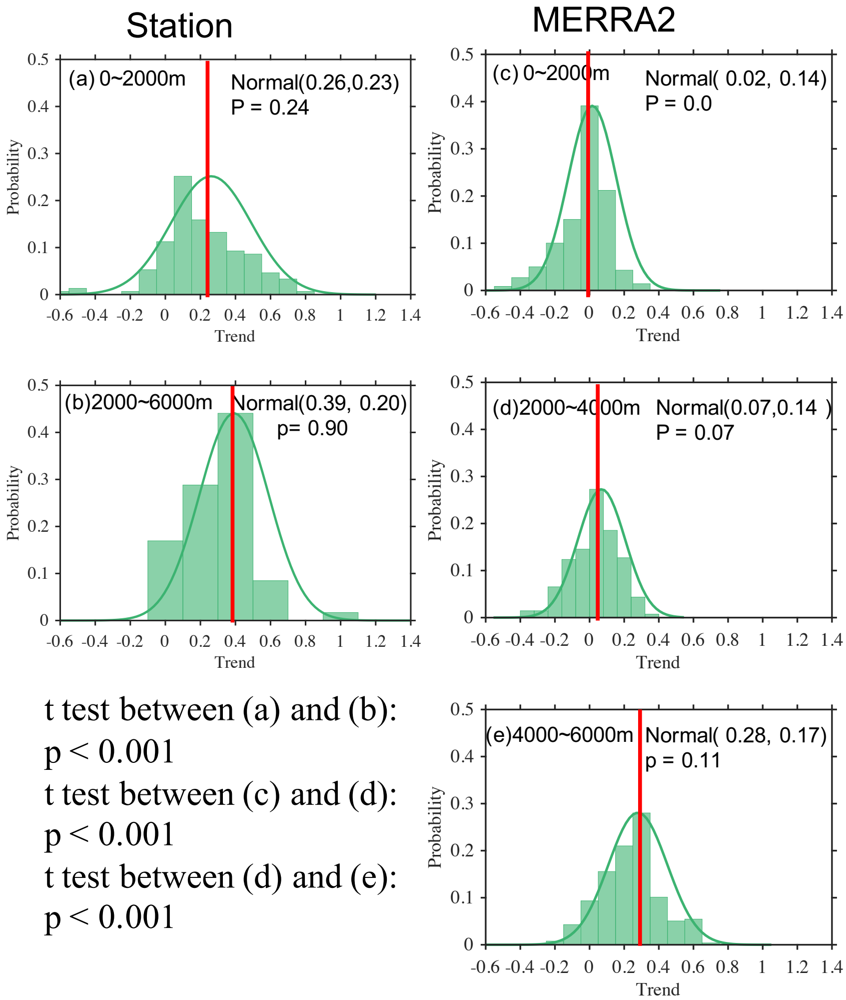

Figure 4. Distribution of probability density function of temperature trend (a, b, observational data; c, d, e, MERRA2 data; units: °C/decade) in the TP and its surrounding areas. The histogram represents the samples size, and the curve is a normal distribution fit line. The red line represents the mean of sample. The means and SDs of the normal distribution fit are also added in the upper right corner of the diagram. (a), (b) indicates the altitude ranges of 0–2000 m, and 2000–6000 m, respectively. (c), (d), (e) indicates the altitude ranges of 0–2000 m, 2000–4000 m and 4s000–6000 m, respectively. All graphs are statistically significant at the 95% confidence level by Kolmogorov-Smirnov test except (c). All mean tests are passed by student t test.

***Comment** 7: Line 220-224: "As shown in Figure 3a, the normal distribution curve of the 2000–4000 meters temperature rate is significantly more concentrated and shifted to the right than that of 0–2000 meters. The average temperature-change rate* *increases from 0.26°C/decade to 0.38°C/decade, and the variance reduces from 0.05 to 0.04." There is no statistical significant test, it is hard to believe the conclusion. In addition, authors shall make clear about how did they obtain the normal distribution of temperature.*

Response: Thanks for your advice, we have added the statistical significant test. Detailed modifications are as follows：

"Kolmogorov-Smirnov test is applied to check the statistical significance of normal distribution. If the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis that the sample follows a normal distribution. "(P2, L175-177).

"The statistical significance of climate mean analysis is determined by the standard two-tailed Student's t test method. "(P2, L184-185).

"As shown in Figure 4a and 4b, the normal distribution curve fit of the 2000–6000 meters temperature rate is significantly more concentrated and shifted to the right compared to that of 0–2000meters. The average temperature-change rate increases from 0.26°C/decade to 0.39°C/decade ($p<0.001$). It can be seen that, with the increase of elevation, the temperature-change rate of the TP and its surrounding areas increases significantly. There is the same phenomenon between the MERRA reanalysis data and the observational data despite difference in value. There are also significant differences between 0-2000 and 2000-4000m layers changes. The average temperature-change rate increases from 0.02°C/decade to 0.07°C/decade ($p<0.001$). Between 2000-4000 and 4000-6000m, the average temperature-change rate increases from 0.07°C/decade to 0.28°C/decade ($p<0.001$). "

Note that, in the revised manuscript, MERRA2 reanalysis data is used to analyze the TP temperature and atmospheric circulation, so the study period was changed to 1980-2016. Therefore, the temperature-change rate has a small change but the overall conclusion remains the same. The results and analysis above have been supplemented in the paper. (P3, L244-252).

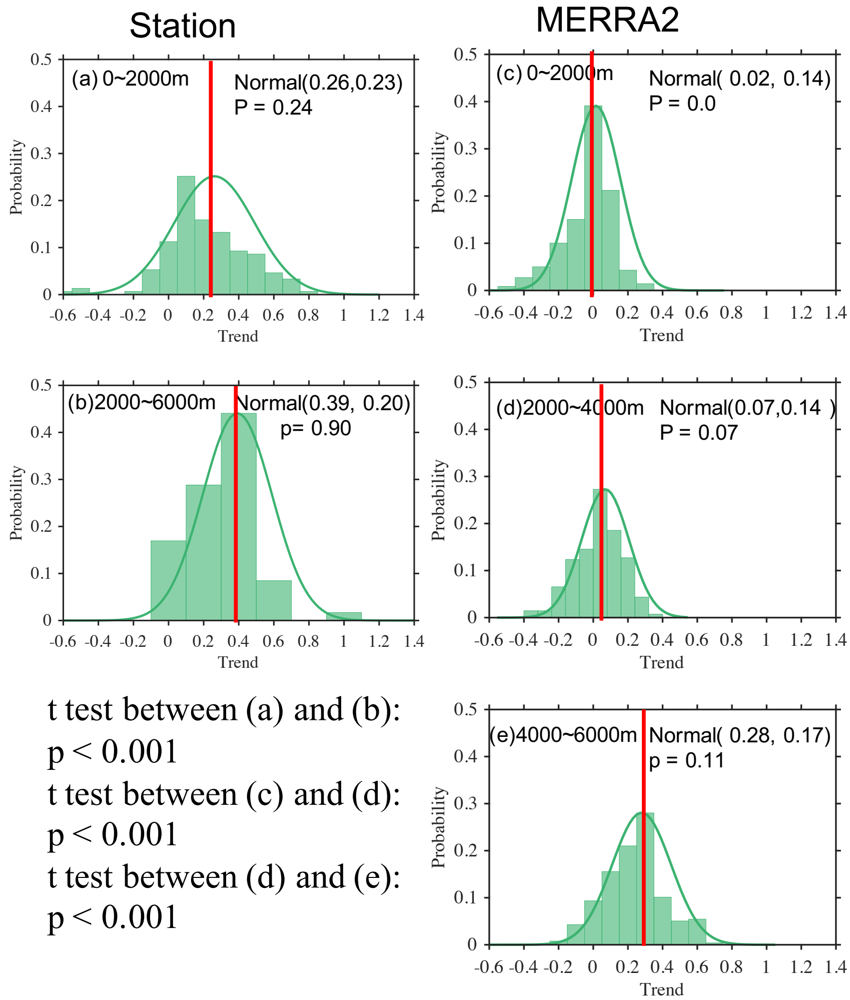

Figure 4. Distribution of probability density function of temperature trend (a, b, observational data; c, d, e, MERRA2 data; units: °C/decade) in the TP and its surrounding areas. The histogram represents the samples size, and the curve is a normal distribution fit line. The red line represents the mean of sample. The means and standard deviation of the normal distribution fit are also added in the upper right corner of the diagram. (a), (b) indicates the altitude ranges of 0–2000 m, and 2000–6000 m, respectively. (c), (d), (e) indicates the altitude ranges of 0–2000 m, 2000–4000 m and 4000–6000 m, respectively. All graphs are statistically significant at the 95% confidence level by Kolmogorov-Smirnov test except (c). All mean tests are passed by student t test.

Comment 8: *Line 238-240: "In this period, the summer precipitation in China is characterized by the so-called "southern flood–northern drought" spatial distribution (Rectangular area from north to south, respectively present north and south eastern*

Asia region).“ The interdecadal variations of summer precipitation over 1979-2016 in China has been investigated in many literatures. Authors should check the literatures and provide precise statement.

Response: Thank you for your valuable comment. We have reviewed the relevant literatures and find that there is a little different with the basic feature of “southern flood–northern drought” that has also been reported by previous literatures (Yu and Zhou 2007; Zhou et al. 2009a; Nigam et al., 2015). The anomalous rainfall pattern is often referred as the South-Flood North-Drought (SFND) pattern, which is performed as a coherent meridional dipole over eastern China, with significant drying in the middle and lower reaches of the Yellow River (where climatological rainfall is less than 4 mm/day) and increasing rainfall across and to the south of the Yangtze River is also evident. Therefore, we have reorganized the sentences and do not quote the SFND pattern. The revised sentences are as follow:

“To verify the reliability of the GPCP precipitation data, the analysis result is compared with the observed site precipitation data. Figure 5 shows the spatial distribution of precipitation change using linear fitting in China (a; observation) and East Asia (b; GPCP) during the summers of 1980–2016. Cross symbols indicate statistical significance above the 95% confidence level. The similar patterns are both displayed in Figure 5a and Figure 5b, which is consistent with the results of previous analyses (Xu et al. 2014; Burke and Stott, 2017; Xu et al., 2018). The precipitation in the south of the Yangtze River, such as South China and Jiangsu and Zhejiang, is generally higher, especially in Jiangsu and Zhejiang provinces. Precipitation in the north of the Yellow River and in Southwest China is generally lower” (P3, L268-275)

Reference:

Yu, R. C., and T. J. Zhou, 2007: Seasonality and three-dimensional structure of the interdecadal change in East Asian monsoon, J. Climate, 20, 5344-5355.

Zhou, T., D. Gong, J. Li, and B. Li, 2009a: Detecting and understanding the multidecadal variability of the East Asian summer monsoon -Recent progress and state of affairs. Meteor. Zeitschrift, 18, 4, 455-467.

Nigam Sumant, Yongjian Zhao, Alfredo Ruiz-Barradas, Tianjun Zhou, 2015: The South-Flood North-Drought Pattern over Eastern China and the Drying of the Gangetic Plain, 437-359pp (Chapter 22) in: Climate Change: Multidecadal and Beyond, edited by Chih-Pei Chang, Michael Ghil, Mojib Latif, John M. Wallace, 2015 World Scientific Publishing Co.

Comment 9: *Line 247-248: "In China, the southern flood–northern drought pattern is also seen with the MERRA data, and is extremely significant. "What is the "extremely significant"? Any test to provide evidence.*

Response: Thank you for your suggests. We have reorganized the language as following: "The similarity precipitation distribution pattern between the site data and GPCP data confirm that GPCP precipitation data well reflects the precipitation in China and even in East Asia. On account of well perform of the GPCP data, in the later cause analysis, we will use GPCP precipitation data to find the TP-EASM relationship after TP warming amplification." (P3, L277-280)
