Response to Referee 2

We would like to thank anonymous Referee 2 for reviewing our revised manuscript as well as the responses. In the following, we address all comments point-by-point according to referee's comments.

The manuscript has been improved with additional explanations of the methods and limitations since last reviewed. I believe that the conclusions are correct, however I still have some comments about the analysis used, particularly for table 5.

Major comments

Table 5, lines 269-276: The authors have clearly addressed the different altitudes over which warming amplification was detected. However I am still concerned about the use of different elevations to determine significant trends. The authors point to studies where EDW was found at high elevations only, and I would suggest that they conduct similar analysis to form a stronger and more meaningful conclusion. If there is a suggestion that altitude dependent warming occurs above a certain threshold (in the discussion, you suggest 4500 m), that threshold can be chosen and all trends analysed on the same grid points above the threshold. Even if this results in fewer significant trends, I believe it will result in more meaningful conclusions. Where many trends are fitted and significant ones are chosen, it increases the likelihood that those that appear significant have occurred by chance. I think the authors have made this clear and evident in their conclusions, but that the analysis could be more focussed to support these conclusions.

-Answer: This is a very important issue. Thanks a lot for referee's constructive comments. The EDW performances may be different using different altitude thresholds. We recalculated the EDW using different altitude thresholds according to referee's suggestion. We replaced Table 5 by other three new tables. Meanwhile, we re-draw the Fig. 2 to Fig. 4. We revised the whole Section 3.2.

Table 5. Significance of elevation-dependent warming for monthly Tmin above different altitude thresholds based on the CTMD from 1979 to 2016.

	All altitude	>2000 m	>2500 m	>3000 m	>3500 m	>4000 m	>4500 m
January	0.039***	0.040***	0.046***	0.049***	0.049***	0.040**	0.023**
February	0.033***	0.020***	0.021***	0.025***	0.028***	0.030***	0.029*
March	0.023	-0.014*	-0.019**	-0.018*	-0.013	0.0	0.018
April	0.021***	0.027***	0.031***	0.032***	0.026**	0.014	-0.002
May	-0.056***	-0.055***	-0.054***	-0.056***	-0.055***	-0.045**	-0.022
June	-0.025***	-0.050***	-0.057***	-0.060***	-0.059***	-0.047**	-0.025**
July	0.0	0.008	0.015***	0.019***	0.022***	0.027***	0.034***
August	-0.011	-0.043***	-0.047***	-0.050***	-0.045**	-0.027	-0.003
September	-0.006	-0.050***	-0.061***	-0.065***	-0.064**	-0.051**	-0.031***
October	-0.073***	-0.104***	-0.109***	-0.112***	-0.104**	-0.074*	-0.026
November	-0.032***	-0.045***	-0.050***	-0.055***	-0.057***	-0.048**	-0.031**
December	0.064***	0.082***	0.092***	0.096***	0.093***	0.074**	0.044**

Note: the positive value indicates the elevation-dependent warming trend while the negative value indicates the elevation-dependent cooling trend. * denotes the significance level p<0.1, ** denotes the significance level p<0.05, and *** denotes the significance level p<0.01.

Table 6. Significance of elevation-dependent warming for monthly Tmean above different altitude thresholds based on the CTMD from 1979 to 2016.

	All altitude	> 2000 m	> 2500 m	> 3000 m	> 3500 m	> 4000 m	> 4500 m
January	0.036***	0.041***	0.046***	0.047***	0.044***	0.033**	0.016**
February	0.012***	0.006***	0.007***	0.009***	0.009***	0.008***	0.008*
March	0.009**	0.002**	0.002***	0.003**	0.003**	0.004**	0.005*
April	-0.020***	-0.007	-0.002	0.001	0.003	0.007	0.012**
May	-0.022***	-0.017***	-0.015***	-0.016***	-0.017***	-0.018***	-0.015**
June	0.007	0.015***	0.018***	0.021**	0.025**	0.034***	0.045***
July	-0.017**	-0.022***	-0.020**	-0.020*	-0.017	-0.004	0.015
August	0.007	0.002	0.006	0.009	0.014	0.024*	0.037***
September	0.003	-0.002	-0.002	-0.002	0.0	0.007	0.017**
October	-0.018***	-0.018***	-0.018***	-0.018***	-0.017**	-0.012*	-0.004
November	-0.031***	-0.025***	-0.022***	-0.020***	-0.018**	-0.013*	-0.005
December	-0.001	0.002	0.004***	0.006***	0.006**	0.007*	0.008*

Note: the positive value indicates the elevation-dependent warming trend while the negative value indicates the elevation-dependent cooling trend. * denotes the significance level p<0.1, ** denotes the significance level p<0.05, and *** denotes the significance level p<0.01.

Table 7. Significance of elevation-dependent warming for monthly Tmax above different altitude thresholds based on the CTMD from 1979 to 2016.

	All altitude	> 2000 m	> 2500 m	> 3000 m	> 3500 m	> 4000 m	> 4500 m
January	0.037***	0.050***	0.057***	0.059***	0.054**	0.036*	0.013*
February	0.008	0.010*	0.017***	0.021***	0.023***	0.019*	0.008
March	0.017***	0.027***	0.026***	0.025***	0.023***	0.023***	0.024***
April	0.002	0.055***	0.069***	0.077***	0.085***	0.090***	0.090***
May	-0.045***	-0.046***	-0.047***	-0.053***	-0.062***	-0.073***	-0.079***
June	-0.046***	-0.069***	-0.074***	-0.081***	-0.085***	-0.075**	-0.048**
July	-0.019**	-0.002	0.006*	0.010**	0.011**	0.013*	0.016
August	0.010	0.007	0.014***	0.019***	0.022***	0.023***	0.023**
September	-0.004	0.005	0.007	0.008	0.012	0.022*	0.038***
October	0.006	0.001	0.004	0.007*	0.008*	0.010	0.017**
November	-0.018***	-0.021***	-0.021***	-0.023***	-0.026***	-0.028***	-0.026***
December	-0.018***	-0.025***	-0.022***	-0.022***	-0.025***	-0.026**	-0.017**

Note: the positive value indicates the elevation-dependent warming trend while the negative value indicates the elevation-dependent cooling trend. * denotes the significance level p<0.1, ** denotes the significance level p<0.05, and *** denotes the significance level p<0.01.

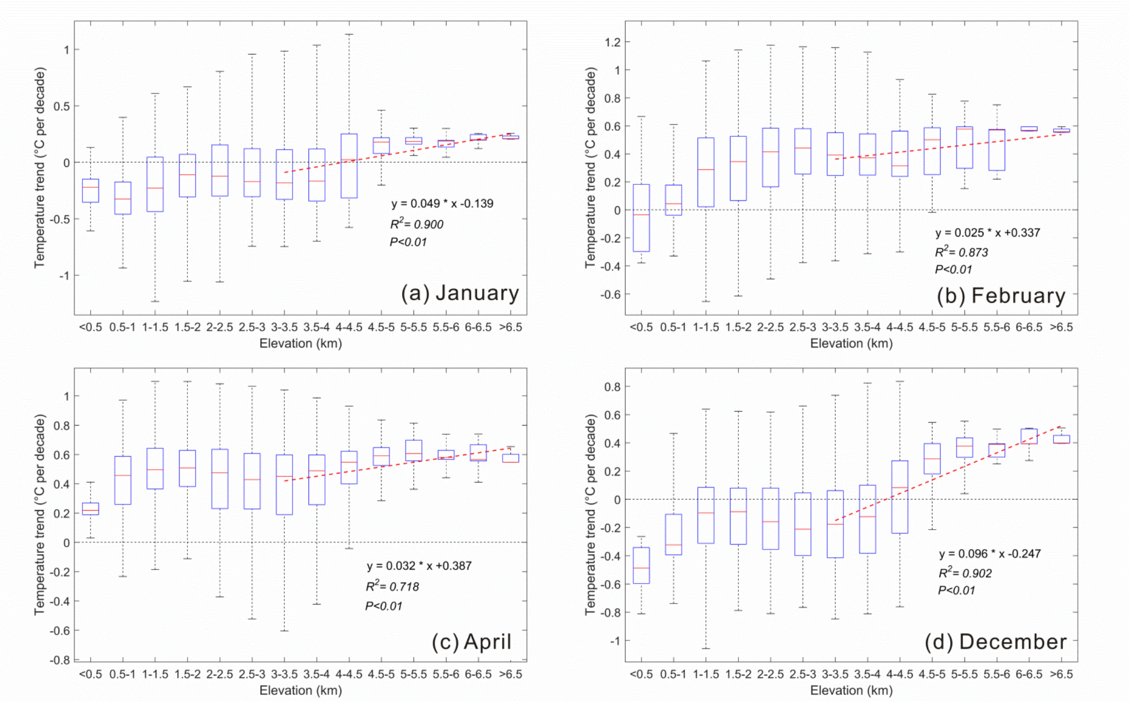

Figure 2: Box plots of monthly minimum temperature trends at different altitudes from 1979 to 2016. (a) January, (b) February, (c) April, and (d) December. Thick horizontal lines in boxes show the median values. Boxes indicate the inner-quantile range (25% to 75%) and the whiskers show the full range of the values. The red dashed lines represent the significance of EDW by fitting the temperature trends and altitude groups above 3000 m.

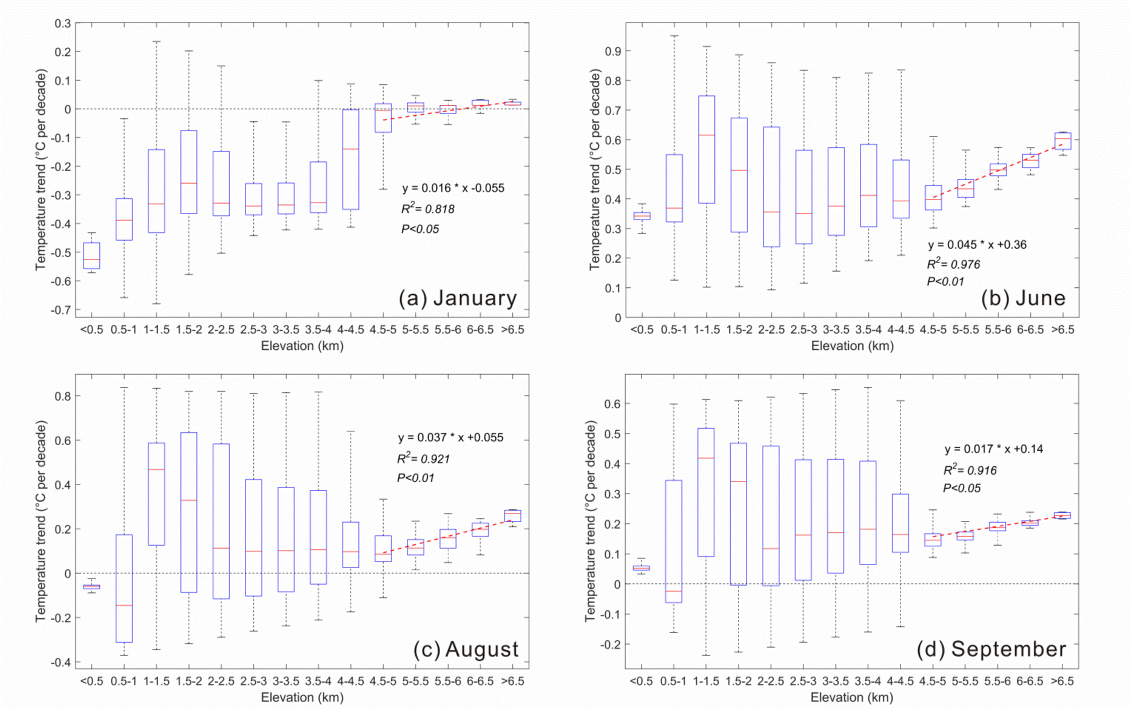

Figure 3: Box plots of monthly mean temperature trends at different altitudes from 1979 to 2016. (a) January, (b) June, (c) August, and (d) September. Thick horizontal lines in boxes show the median values. Boxes indicate the inner-quartile range (25% to 75%) and the whiskers show the full range of the values. The red dashed lines represent the significance of EDW by fitting the temperature trends and altitude groups above 4500 m.

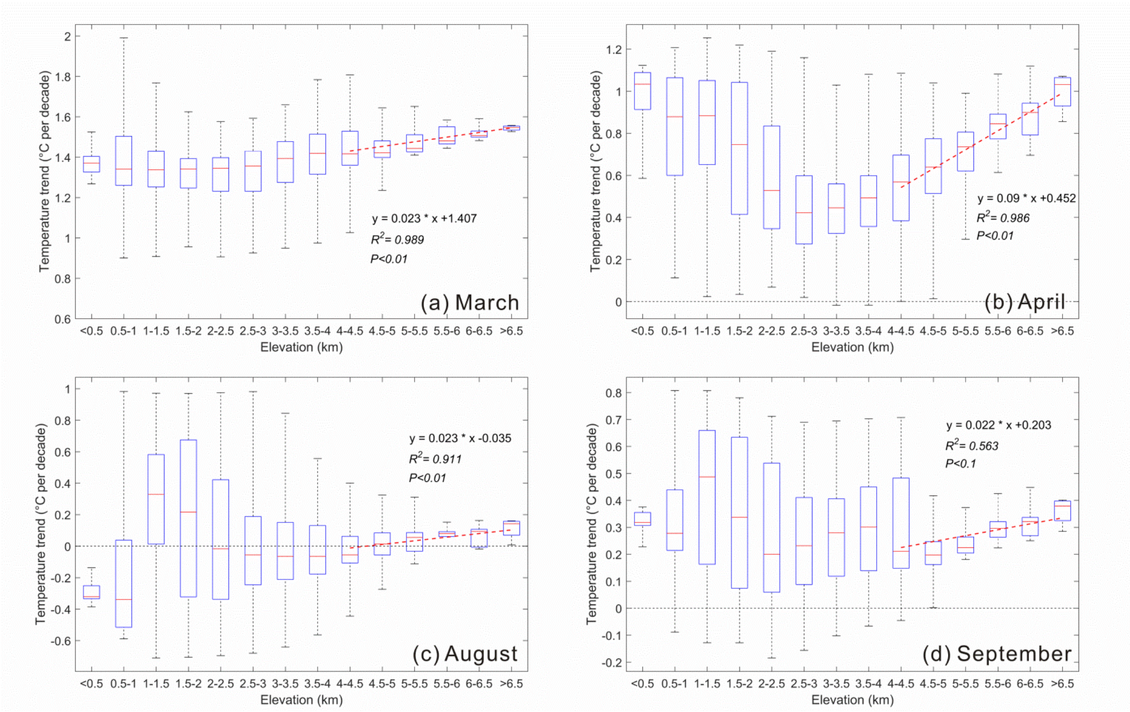

Figure 4: Box plots of monthly maximum temperature trends at different altitudes from 1979 to 2016. (a) March, (b) April, (c) August, and (d) September. Thick horizontal lines in boxes show the median values. Boxes indicate the inner-quartile (25% to 75%) and the whiskers show the full range of the

values. The red dashed lines represent the significance of EDW by fitting the temperature trends and altitude groups above 4000 m.

Table 5 to 7 summarized the warming amplification with altitude for monthly Tmin, Tmean and Tmax over different altitudes from 1979 to 2016, respectively. The slope of fitting line between monthly temperature warming trends and altitude groups illustrated the significance of EDW above different altitude thresholds. For Tmin, the EDW could be found at full altitude (204-7100 m) in winter (January, February, and December). However, the most significant EDW appeared at altitudes above 3000 m in January and December (Table 5). The EDW was significant for April Tmin at altitudes below 3500 m. The EDW begins to appear above 2500 m altitude, but it is most significant above 4500 m in July (Table 5). The 4500 m is the threshold for the most significant EDW for Tmean in April, June, August, and September (Table 6). However, the EDW appeared at altitude above 2000 m in June. From January to March, the EDW exists over all elevation groups. The most significant EDW was found at the elevation higher than 3000 m in January (Table 6). The Tmax in January, March and April showed the EDW over the whole elevations, but at different altitudes for the most significant EDW (Table 7). Above 3000 m altitude, the most significant EDW was found in January while above 2000 m in March. The EDW become more and more significant from 2000 m to 4000 m in April. From August to October, the 4500 m was the threshold for the most significant EDW (Table 7). In general, the altitudes at which the EDW phenomenon appeared are different for three temperatures in twelve months. The EDW differences (slope values) demonstrated the magnitudes of warming amplification at different altitudes. For example, for Tmin, the most significant EDW could be detected at the altitude 3000 m in winter. For Tmax, the EDW could be detected above 2000 m and 2500 m in April and August, respectively. However, the most significant warming amplification with altitude was found above 4000/4500 m in these two months (Table 7).

As the further explication of Table 5 to 7, Fig. 2 to Fig. 4 intuitively provided the temperature trends at different altitude groups as well as the significance of EDW *above different altitude thresholds. Fig. 2 showed the Tmin warming trends in January, February, April, and December from 1979 to 2016. The fitting between temperature trends and altitude groups above 3000 m illustrated the warming amplification with altitude. As the number of grids in each elevation group is different, the boxplots show the interquartile range (25% to 75%) and median values. To maintain consistent trend calculation for the entire study, the average value was used for linear regression. Meanwhile, linear regression was applied based on the average values, which indicated the altitude dependence of the warming trend (i.e. the significance of EDW). In general, the EDW characteristics were significant for Tmin in January, February, April, and December. All lines of best fit are at the 0.01 significance level ($p < 0.01$). The temperature trends were positive at altitudes higher than 5000 m, with median values greater than 0 ℃ $10a^{-1}$ above 4000 m in January (Fig. 2a). The median values of most elevation groups were above the reference line in February, although the corresponding line of fit had a lower slope (0.025) compared with that of January (Fig. 2b). The 75% quartile ranges of the trends for all elevation groups in April were higher than 0 ℃ $10a^{-1}$ (Fig. 2c). All trends were positive for the regions above 4000 m in April. The prevalence of EDW was the most significant in December with the highest slope (0.096, $p < 0.01$). Although, most of lower altitude grids (< 4000 m) showed negative warming trends, the trends become positive at altitudes higher than 5000 m (Fig. 2d).*

Fig. 3 showed the Tmean warming trends in January, June, August, and September from 1979 to 2016. The altitude threshold was 4500 m. The warming rates in January were only slightly above 0 ℃ $10a^{-1}$ at higher elevations. The significance of EDW was at the 0.05 significance level with a slope of 0.016 (Fig. 3a). The most significant EDW (slope = 0.045, $p < 0.01$) was found in June with all positive trends at all altitudes (Fig. 3b). The second significant EDW occurred above an elevation of 4500 m in August (slope = 0.037, Fig. 3c). The warming rates were above 0 ℃ $10a^{-1}$ at higher elevations (> 4500 m). The fitting slope is 0.017 at the 0.05 significance level in September (Fig. 3d).

A threshold of 4000 m was applied for the significance of EDW investigation for Tmax in March, April, August, and September (Fig. 4). Although the slope (0.023) of the trend was not remarkable, all warming rates were greater than 0.8 ℃ $10a^{-1}$ in March (Fig. 4a). A significant elevation-dependent cooling could be observed in the altitude range of 0–2500 m for Tmax in April. However, the most significant EDW also was detected above the altitude of 4000 m (slope = 0.09, Fig. 4b). Most of the warming rates were higher than 0.4 ℃ $10a^{-1}$ in April. The EDW occurs at higher height of 4000 m in August and September (Fig. 4c and 4d). However, the EDW is more significant above 4500 m in September than that above 4000 m (Table 7). The temperature trends for all months and seasons are also provided in the supplementary material (Fig. S1-S13). Previous studies also found that EDW is significant at different altitudes. For example, Li et al (2020) found a significant EDW in the altitude of 2500–5000m from 1980-2012 in the high mountain Asia. You et al (2020) concluded a clear EDW above 2000 m in the Tibetan Plateau in 1961-1990.

Figure 5: It is not clear to me the advantage of showing one transect where elevation and warming trends are both increasing in the subplots. The transects shown here do not give an indication of whether the elevation is the determining factor, just that (e.g. in figure 5), both elevation and temperature trends increase from west to east. The figure 1 included in the authors response suggests to me that there may be many transects where the temperature trend is decreasing with altitude, indicating there may be another control on warming rates, rather than elevation. I would suggest these subplots are removed, or changed to plots of elevation versus temperature trend over the entire sub-region.

-Answer: Thanks a lot for the comment. We fully understand the referee’s doubts. As shown in Figure 1 in the last pee-review, there are indeed typical EDW phenomenon on some transects, not just shown in the subplots in Figure 5. As the referee pointed out, such a subplot could lead to misunderstandings, and it cannot represent the entire zone. Therefore, we removed the subplots from Figure 5-7 in the revised manuscript according to the referee's suggestion.

At the same time, the referee pointed out an important issue. There are indeed many EDW phenomena in the west-east transect. However, there are also some elevation-dependent cooling phenomena (please see blue rectangle in the Figure 1). Thus, on the other hand, it reflects the complexity of temperature changes in high mountains. For sure, the altitude is not the only factor for the temperature variations. The slope and aspect are other important factors responsible for the temperature changes due to the widespread valleys in the CTM. The local micro-terrains directly affect the absorption of solar radiation which would change the land surface processes such as latent heat, sensible heat and evapotranspiration. In order to explain this issue more clearly, we added discussion in the revised manuscript in the Section 3.3, and also added the Figure 1 in the Supplementary Material (Fig. S31) for readers' better understanding.

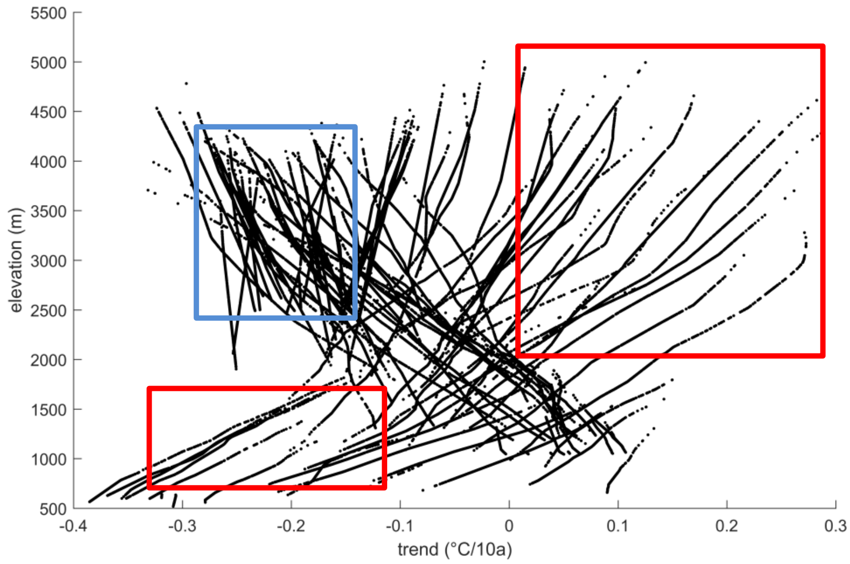

Figure S31: Scatter of December minimum temperature trend and elevation in Zone 2. The grids in the red rectangle show the elevation-dependent warming while the grids in the blue rectangle show the elevation-dependent cooling.

<u>*Figures 5 to 7 show the general features of EDW in four typical areas. Taking Zone 2*</u>

as an example, Fig. S31 showed the warming rate of minimum temperature in December was amplified with elevation in some certain transects (the grids in the red rectangles). However, there are also some elevation-dependent cooling phenomena in Zone 2 (the grids in the blue rectangle). It reveals that altitude is not the only factor that affects temperature changes. The slope and aspect are other important factors responsible for the temperature changes due to the widespread valleys in the Zone 2. The local micro-terrains directly affect the absorption of solar radiation which would change the land surface processes such as latent heat, sensible heat and evapotranspiration. Thus, the EDW should be further detected on a finer spatial scale in some specific areas.

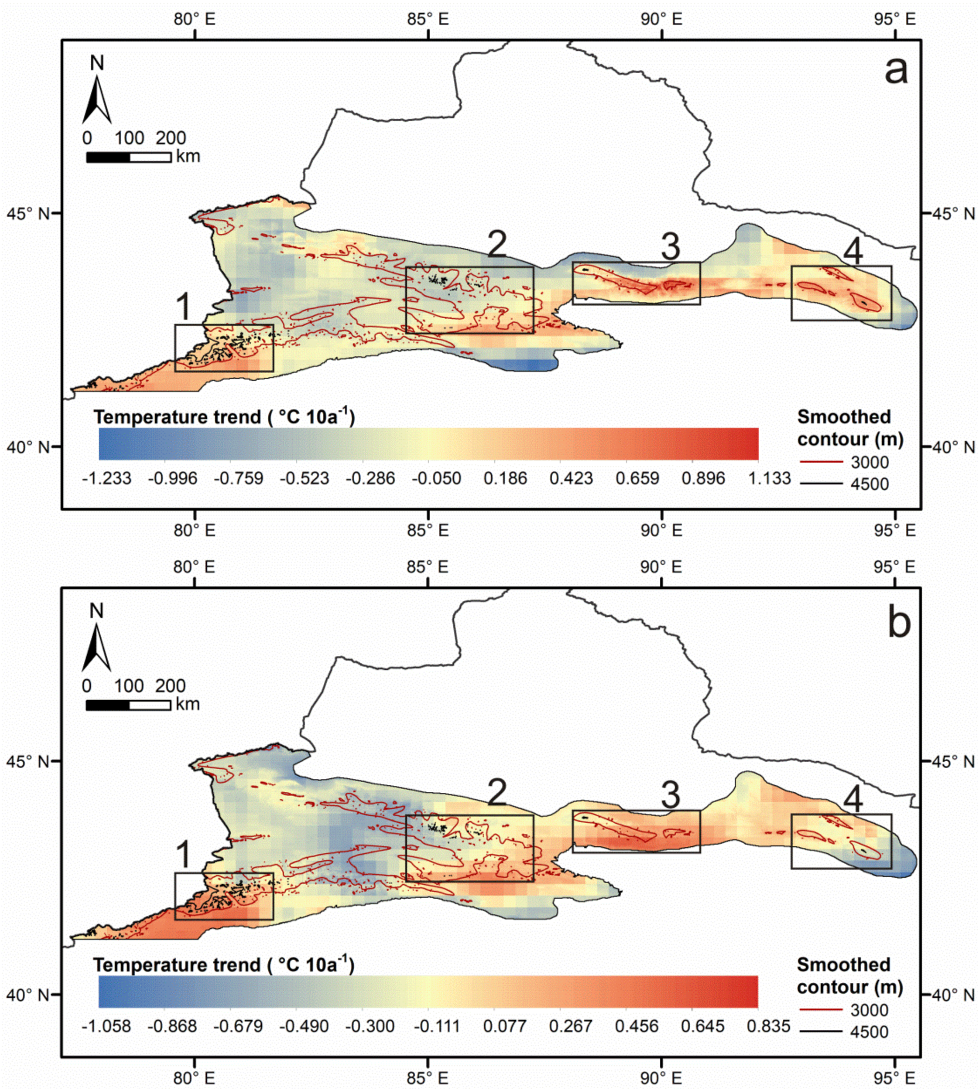

Figure 5: Monthly minimum temperature trends (a) January and (b) December for the

entire CTM from 1979 to 2016.

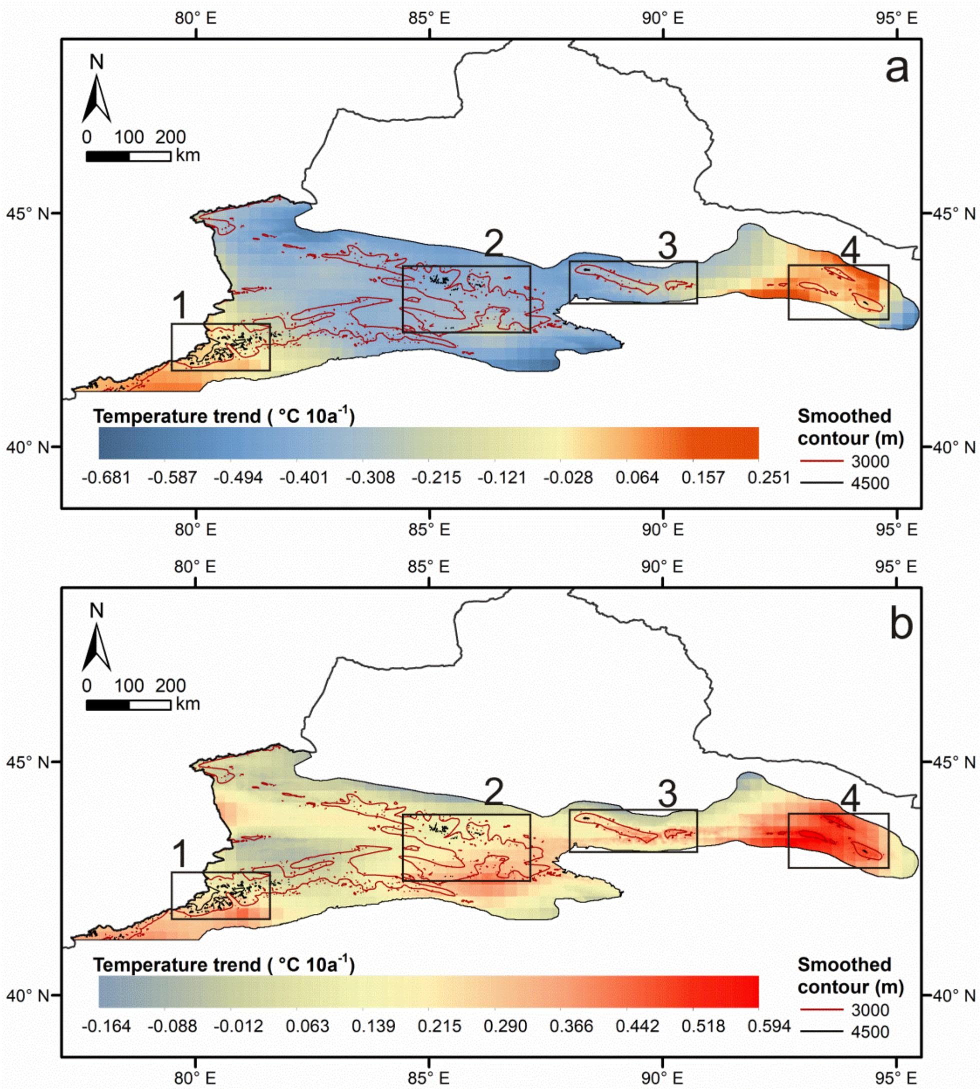

Figure 6: Monthly mean temperature trends (a) January and (b) February for the entire CTM from 1979 to 2016.

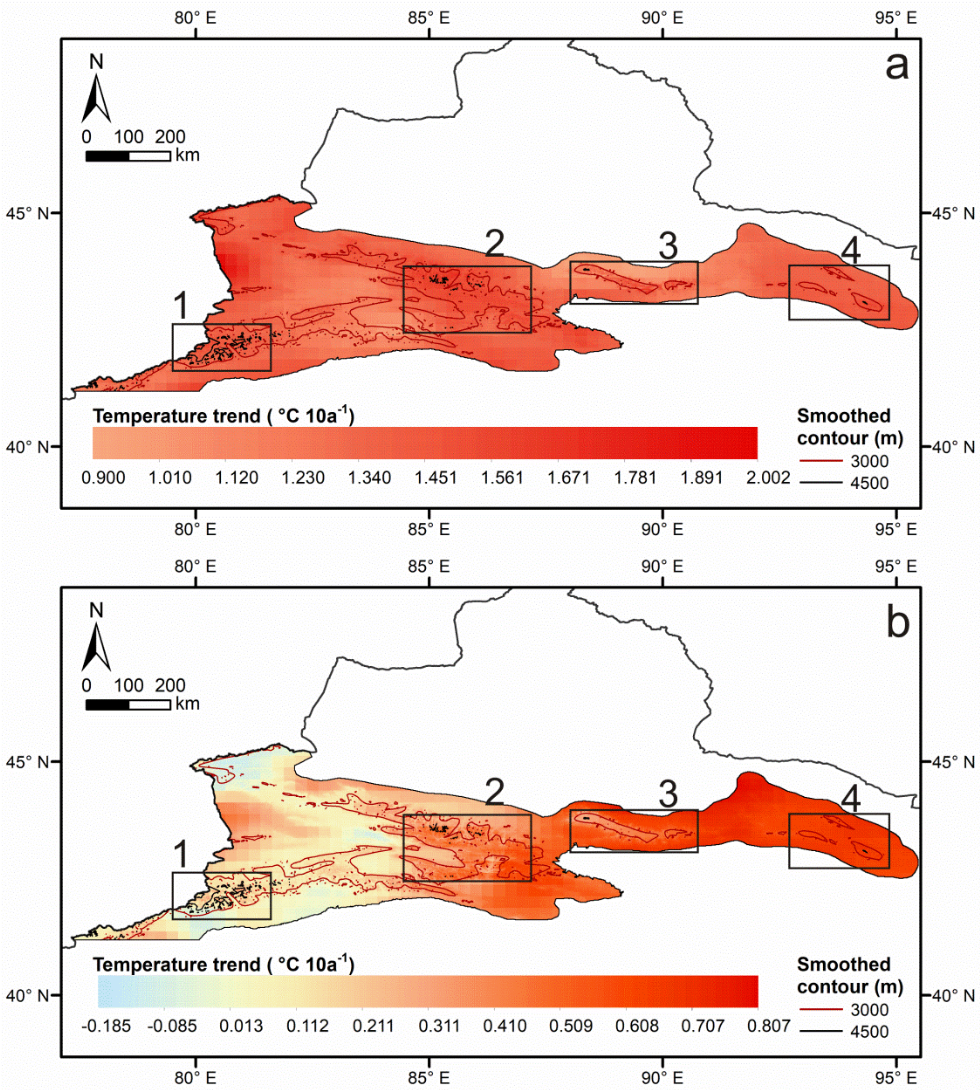

Figure 7: Monthly maximum temperature trends (a) March and (b) September for the entire CTM from 1979 to 2016.

Table 2: I can't quite work out what this is showing, what is the significance of, and where are the different significance levels? Is this the percentage of grid points in the entire CTM that show significant warming trends? If so, which significance level is being used?

-Answer: Thanks a lot for the comment. The Table 2 was added in the last review round according to a referee's comment. The referee wanted to know how many grids reach the significance levels. Thus, we counted the percentage of grid points in the entire CTM that show significant warming trends. However, here we counted the sum of grids reach three significance levels (p < 0.1, p < 0.05, and p < 0.01) for Tmin, Tmean and Tmax. For better understanding, we provide more statistics in the revision.

Table 2. Ratio (%) of grids at different significance levels ($p < 0.1$, $p < 0.05$, and $p < 0.01$) to total grids (356133).

	Tmin			Tmean			Tmax		
	p<0.1	*p*<0.05	*p*<0.01	*p*<0.1	*p*<0.05	*p*<0.01	*p*<0.1	*p*<0.05	*p*<0.01
January	1.57	1.47	0.24	2.65	1.00	0.00	4.38	2.10	0.00
February	5.18	4.48	0.01	0.55	0.00	0.00	23.50	27.28	5.87
March	17.26	21.26	13.50	4.30	19.61	75.44	0.54	7.57	91.88
April	3.09	0.66	0.00	8.93	14.26	45.97	8.13	19.05	19.18
May	11.78	15.99	19.19	12.47	16.31	0.44	3.74	3.76	0.13
June	16.25	24.04	40.04	11.71	24.76	55.91	6.63	6.95	36.06
July	9.71	15.10	22.05	4.20	4.46	43.31	4.09	9.99	24.74
August	8.21	12.96	14.40	9.86	8.06	38.45	13.70	10.67	16.47
September	6.82	10.67	2.38	4.30	18.36	25.11	9.12	10.57	15.63
October	6.01	5.58	0.18	12.47	13.05	0.00	5.44	5.66	0.31
November	6.00	4.98	1.02	8.64	5.43	0.00	7.55	6.57	0.00
December	0.30	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Minor comments

Line 179: please make it clear here that while the 6-hourly data were aggregated to monthly, seasonal and annual time scales, Tmin and Tmax were picked as one of the 4 available UTC times (and which these were). Similarly for line 197.

-Answer: Thanks a lot for pointing this out. We added the specific information in this part. The four times are 00, 06, 12, 18 UTC. The monthly Tmin and Tmax are calculated from the daily Tmin and Tmax, respectively, according to these four UTCs.

Line 209: grammatical error: " WCC and LCC that represented by excluding the CTM and the QTP from the WCC" -> "WCC and LCC which is represented by excluding the CTM and the QTP from the WCC". Also a general note, that removing some of the acronyms in this paper would greatly improve readability.

-Answer: Thanks a lot for pointing this out. We revised this grammatical error and we also removed some other acronyms in the revision. For example: "*...and LCC that which is represented by excluding the Tianshan Mountains and the Qinghai-Tibetan Plateau from the whole continental China.*"

Figures 5-6: Please indicate either in the figure captions how the place names correspond to the zones (e.g. where is the Ili valley, Tolm mountains?)

-Answer: Thanks a lot for the comment. This is a very important suggestion. We labeled the important places in Figure 1 in the revision.

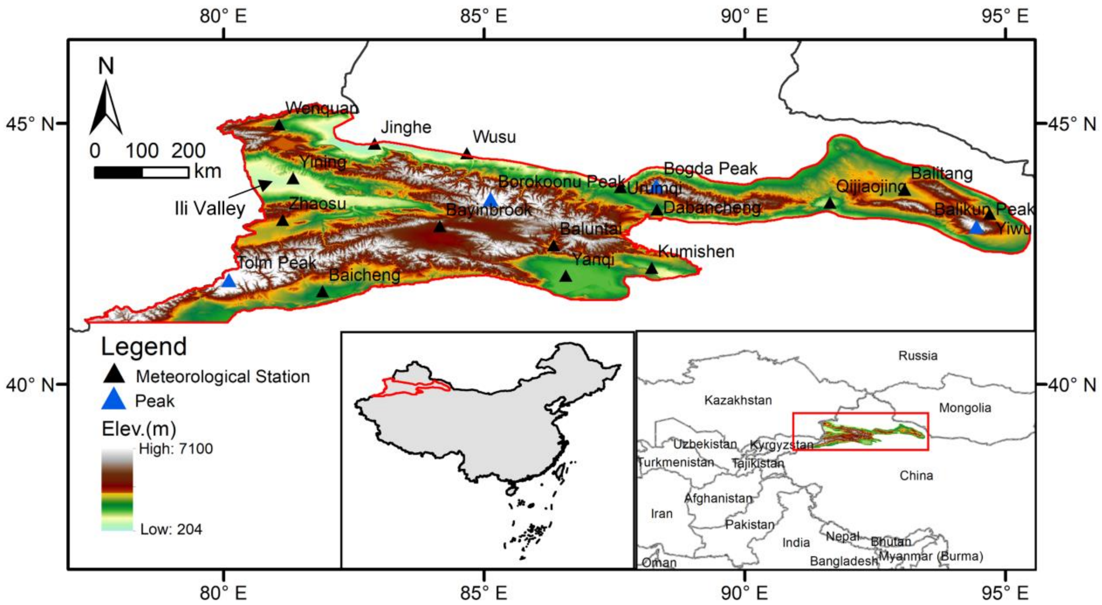

Figure 1: Location of the Chinese Tianshan Mountains (CTM).The elevation ranges from 204 m to 7100 m a.s.l., with a DEM resolution of 1 km from SRTM. The grey sub-plot show the extent of the CMA05 at the 0.5 °×0.5 °grid.