**Climate
of the Past
Discussions**

Interactive comment on "Modeling the climatic implications of the Guliya δ^{18}O record during the past 130 ka" *by* D. Xiao et al.

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Response to Interactive comment 2 on "Modeling the climatic implications of the Guliya δ18O record during the past 130 ka" by D. Xiao et al.

Anonymous Referee #2

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The authors made an interesting effort trying to understand better the climatic significance of the Guliya delta 18O through climate modeling. This approach is new to my knowledge. It is certainly an interesting and important topic given the unique location of the Guliya ice core. However, in order to make their conclusions more convincing and their analysis more in depth, the following points must be improved and answered.

Response: Thanks for your important comments on this manuscript. We have greatly modified the manuscript according to your comments and suggestions.

Major concerns:

1. The research motivation should be more clearly addressed in Introduction.

Response: We have rewritten the research motivation in introduction to make it clearly be presented. For example, in the first paragraph of the introduction, we introduced the detailed geographical condition of Guliya ice core and the previous studies using the Guliya temperature record. In the second paragraph, we illustrated the influences of astronomical parameters on Guliya δ18O. In the third paragraph, we proposed some unresolved issues on the Guliya δ18O and our purpose.

Please see them in the modified manuscript.

2. Regarding the experiments, information on initial conditions and boundary conditions is needed. Are other climate forcings (e.g. ice sheets, greenhouse gas concentration, : : :) kept constant through the whole simulation? How long did the model take in real time for 1308-year long simulation? Is it worth to use acceleration for an intermediate complexity model? The readers may also want to know the disadvantage and possible bias induced by the acceleration technique.

Response: The other climate forcings used in this study, such as ice sheets, greenhouse gas concentration and solar insolation (solar constant) are set to the constant at the year 2000 AD through the whole simulation. The authors added the above sentence in the second paragraph in Section 2 in Line 16–18, Page 8.

The UVic Model expended approximately seven months (210 days) to run 130.8 ka without the acceleration scheme and two days to run 130.8 ka (1308 model year) by the acceleration scheme with a factor of 100. Accelerated simulation is economical and is worth to apply acceleration for the long-term integration using an intermediate complexity model such as UVic Model.

Indeed, some disadvantages and possible biases would be induced by the acceleration scheme. For example, Timm and Timmermann (2007) found that deviations from the non-accelerated simulation are expected to occur in particular in the Southern Ocean, in regions of deep-water formation, large thermal inertia, and below the thermocline. The response of surface atmospheric and oceanic variables to astronomical forcing is expected to be largely unaffected by the acceleration technique. Therefore, we focus on the indicative senses of Guliya δ18O in the middle and low latitudes. We add the associated descriptions in Line 5–10, Page 8.

3. P1891, 2nd paragraph: The authors only described Fig1 and did not attempt to give any explanation. I suggest they plot the similar figure as Fig1 but for insolation to see if the variation of SAT can be explained by variation of insolation. Moreover, the last sentence of this paragraph must be corrected because the fact that the insolation distribution differs between months is well known from the astronomical theory of Milankovitch 1941 and Berger 1978.

Response: We have added the annual cycle of incoming solar radiation anomaly over Guliya in the past 130 ka as Figure.1a of the revised manuscript (Figure A of this reply) and associated descriptions. Additionally, we have also explained the variation of SAT anomalies from that of incoming solar radiation which is well known from the astronomical climatic theory of Milankovitch (1969) and Berger (1978). Please see the descriptions in the first and second paragraphs of Section 3.

4. 3rd paragraph of Section 3:

(1) More details about the correlation between Guliya delta 18O and simulated temperature should be given. What is the phase relationship between delta 18O and each monthly temperature? If such a phase is taken into account, what is the impact on the conclusion? What is the accuracy of the time scale of the delta 18O, and its impact on the result?

Response: There is little impact on our conclusion when the phase of each month

is taken into account. We calculated the correlation coefficient between the Guliya δ18O and the simulated SAT in each month. The correlation coefficients in January– April are negative and significant at the 95% confidence levels. Because the Guliya δ18O had been identified as a temperature index (Yao et al., 1996), such negative relationship reflects that the winter (January–April) Guliya SAT (δ18O) is higher while the Guliya incoming solar radiation is smaller than normal. It is difficult to give a physical explanation why the Guliya δ18O is out-phase with the simulated SAT in January–April because such fact violates the basic physical principle. From a statistical view, the out-phase relationship between Guliya δ18O and the simulated SAT in January–April may be caused by the 21-ka cycle of precession, namely the half-cycle phenomenon, for example, the red peak of 11.179 of Guliya δ18O. Considered the consistency of both the statistics and physics, we conclude that the Guliya δ18O may indicate the August–September SAT, with a positive correlation coefficient of 0.47.

The temporal resolution of Guliya δ18O is inhomogeneous, and is approximately 0.07 ka on average. There are 1875 samples sizes in the Guliya δ18O data during the past 130 ka, more than that in the acceleration model results with a samples size of 1308. The temporal resolution of Guliya δ18O does not influence the result. We indicated the samples sizes of Guliya δ18O data in Section 2.

(2) The authors try to determine to which month SAT the delta 18O is the most correlated by comparing their simulated monthly temperature with delta 18O. How does it compare with the correlation obtained from statistical analysis of delta 18O and monthly temperature provided by modern observation?

Response: Because the resolution of Guliya δ18O is approximately 0.07 ka, it is difficult to compare the Guliya δ18O with the modern gauge monthly temperature. Despite of this, Yao et al. (JGR, 1996) showed the correlation between the δ18O and the modern gauge monthly temperature. Their result shows the similar annual cycle in both δ18O and gauge monthly temperature of three nearby meteorological stations (Figure B), with strong linear relationship (Fig. 3 in the work of Yao et al. (1996)) and high

correlation (Zhang et al., 1995). Yao et al. (1996) also indicated there was a modest enrichment in annual average Guliya δ18O. The August–September observed air temperature nearby the Guliya ice core also show a modest warming trend during the same period (Shi et al., 2002), which suggests that the August–September observed air temperature also consistent with the variation of Guliya δ18O on decadal to longer time scales.

(3) The conclusion that the Guliya delta 18O represents late-summer temperature is not convincing enough before answers to the questions in (1) and (2) above are provided. Nevertheless, even if one accepts this conclusion, the mechanisms which link the late-summer SAT with the delta 18O must be explained.

Response: The mechanisms link the SAT with the Guliya δ18O had been explained in modern observation data (Zhang et al., 1995; Yao et al., 1996). Guliya δ18O is identified as a temperature index of Tibetan Plateau. We compared the Guliya δ18O with the modeled SAT and find the consistency between them. Meanwhile, we should also note that it is difficult to completely explain the mechanisms linking delta 18O with the August–September SAT in the past 130 ka because the δ18O is only a temperature proxy from the geological record. It needs more work to demonstrate it. Our work also tries to do so.

(4) Based on the high correlation between the Guliya delta 18O and NH summer temperature, the authors conclude that the delta 18O represents not only local temperature but also the NH one. This can be easily questioned because (i) high correlation may due to their similar response to a common forcing (insolation);

Response: We agree with you. Due to the latitudinal inhomogeneity of incoming solar radiation because of precessional motion, the incoming solar radiations over Guliya (35°N) and Arctic are not in-phase (Figure.C). However, the area weighted NH and Guliya averaged incoming solar radiations varied similarly and are in-phase (Figure. D). Therefore, Guiya SAT behave the potential presentation to the NH SAT. Because of

their consistency in variability, we only address that the Guliya δ18O may represent a larger-scale SAT.

(ii) ice sheets which may play important role in the mid-high latitudes are not taken into account in this paper as far as I see;

Response: Indeed, the ice sheets possibly play an important role in in the middle to high latitudes, especially on the glacial cycle time scale. However, the Guliya δ18O does not present obviously the glacial cycle in the past 130 ka. Moreover, the UVic Model without the ice cover model can also capture the major varying features of the Guliya δ18O. These shows that the glacial cycle (ice sheets) may not be a major factor of influencing the Guliya δ18O, supporting the previous studies (Yao et al., 1997; Shi et al., 2000). Therefore, we set the ice sheet to a constant of the 2000 AD. Of course, it is useful to do the similar study using a coupled climate model with dynamic ice cover model in the future.

(iii) the Guliya delta 18O in figure4 shows strong precessional signal but weak obliquity signal and much less clear 100-ka glacial cycle. Is this the case in other NH paleo-records? The authors could compare the Guliya delta 18O with other proxies from different latitudes in the NH to see if Guliya delta 18O represents well the NH temperature.

Response: Among the main ice core proxy data, the Guliya δ18O is the only one with more obvious precession than the 100-ka glacial cycle. We check some of Stalagmite proxy data in the NOAA Paleoclimatology Data Center. Such situation also exists in the others δ18O, such as Stalagmite data in Sanbao Cave (110°E, 31°N) (Wang et al, 2008), and also in southern subtropical Brazil (Cruz et al., 2005), Even in Vostok atmospheric Guliya δ18O in Antarctic (Wang et al, 2008).

Moreover, the Guliya δ18O represents the local August–September temperature and may also represent SAT in many regions of the NH in August–September, but not indicating the SAT over the entire NH in other months, which may be seen in Fig. 10

of this revised manuscript. The NH temperature proxy in the August–September could not be seen in the previous studies. According to your suggestion, it needs to compare other NH paleo-records with the model data in the future work.

5. I try to understand what is the purpose of comparing the climates between the warm and cold phases in Section 4. Please address this more clearly.

Response: This section aims to understand the difference between the warm and cold phases of precession of Guliya SAT. Because if we know a climate cold (warm) state of Guliya SAT (Guliya δ18O), we could speculate the corresponding warm (cold) state of horizontal SAT. These differences are made to try to extend the spatial scale of the simulated Guliya SAT, namely the Guliya δ18O, which are widely used in modern climate statistical analysis.

6. Section 4:

(1) The author should give explanations about the temperature changes described in both 2nd and 3rd paragraphs. They may first check what are the differences in astronomical parameters and in insolation between these warm and cold phases, and then look if these differences can explain their simulated temperature change.

(2) I understand that the authors would like to investigate the impact of obliquity and precession on the differences between the two anomalous patterns in Fig7. However, why not use directly obliquity and precession curves in Fig8 instead of the simulated Arctic temperature? I suggest therefore to replace the Arctic temperature curve by the precession and obliquity curves in Fig8. If they do so, according to the drawing I have made, they might find that for the first type of anomalous pattern, the precession minima (maxima) and obliquity maxima (minima) are more or less in phase which strengthens the insolation anomalies (positive or negative) in the NH summer, and for the second type of anomalous pattern, they are more or less anti-phase which weakens the insolation anomalies in the NH polar latitudes (similar discussions on the impact of precession and obliquity on insolation and climate can be found in Yin and Berger

2012 Climate Dynamics 38,709-724 and in Yin and Berger 2010 Nature Geoscience 3(4),243-246). It is therefore not appropriate to say in lines 10-11 of page 1894 that the second pattern is mainly influenced by precession. It is influenced by both obliquity and precession but these two counteract with each other. The same remains for lines 11-13 of page 1895 and in Section 6.

Response: We have reorganized the manuscript and adjusted Figure 8 of the old manuscript to Figure 7 of the revised one. Due to the latitudinal inhomogeneity of incoming solar radiation because of precessional motion (Figure.C), Figure.E displays the obliquity parameter and simulated Guliya August–September SAT (showing the local influence of precession) to indicate the phase relationship between obliquity and precession in the past 130 ka. As the your comments, the warm (cold) phase of the precession cycle in the simulated Guliya August–September SAT, associated with the first type of anomalous SAT pattern, more or less superposed on that of the obliquity cycle (Figure.E), while the warm (cold) phase of the precession cycle in the Guliya simulated SAT, associated with the second type of anomalous SAT pattern, are more or less counteracted by cold (warm) phase in the obliquity cycles (Figure.E). Therefore, we changed the Figure 7 in the manuscript and corresponding descriptions. Please see them in the last paragraph of Page 14.

7. Page 1895, L19-20: it would be nice to confirm the authors' conclusion by comparing the Guliya delta 18O and a SST proxy from North Atlantic.

Response: According to your suggestion, we checked some reconstructed Atlantic SST data in the NOAA Paleoclimatology Data Center. There are four datasets focus on the North Atlantic SST covering the past 130 ka. However, the resolution is generally too low in these datasets (with only approximately 35–306 samples). More importantly, there is an obvious difference in reconstructed North Atlantic SST proxies between these four datasets. Thus it is difficult to compare the Guliya δ18O or with the simulated SAT with 1308 samples over the North Atlantic. However, we also selected the highest resolution equatorial Atlantic SST with a sample size of 885 dur-

ing the past 130 ka (Weldeab et al., 2007). After interpolated into 1308 model year, the correlation coefficient between the equatorial Atlantic SST at 2°30'N, 9°23'E and Guliya δ18O is 0.18, significant at the 90% confidence level. The value of correlation coefficient is generally equal to that over the equatorial Atlantic (0.21) in the Fig.9 in the manuscript. This consistency also supports the reliability of the model result. We added this comparison in the modified manuscript.

8. One of the important conclusions of this paper is that N. Atlantic SST leads the Guliya late-summer SAT by 2.5ka. Can the author find a justification for this phase relationship by comparing the Guliya delta 18O and a SST proxy from North Atlantic? Speculations are made in the 3rd and 4th paragraphs of Section 5. In order to make this conclusion solid, the authors could do some additional sensitivity experiments to test the impact of North Atlantic SST on the Guliya temperature (these kinds of experiments would not take long time for a model of intermediate complexity).

Response: As said in the response to the comment 7, the current reconstructed North Atlantic SST is not very suitable to used to compare the phase relationship with the Guliya SAT because the resolutions of reconstructed North Atlantic SSTs are relatively low and not homogeneous through the entire 130 ka. The sample sizes of the North SSTs from the Lawrence et al. (2010) , Maetinez-Garica et al. (2010), Oppo et al. (2006) and Bard et al. (2000) are 40, 35, 306, and 205, with averaged resolution of 3.3, 3.7, 0.47 and 0.64 ka. The first two datasets couldn't be used to compare the phase relationship with the Guliya δ18O because the resolution of them can't identify the 2.5 ka lagging and leading relationship. The North SST contributed by Oppo et al. (2006), located at high latitude, mainly tracked record in the glacial cycle. The resolution of North SST contributed by Bard et al. (2000) are much lower (approximately 1–2 ka) before the 80 ka BP, which also is not very suitable to be used to identify the 2.5 ka lagging and leading relationship accurately after interpolated into the 1308 model year. Generally, the resolutions of reconstructed North Atlantic SSTs are relatively low and not homogeneous in the entire period, which, after interpolated into the 1308 model

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year, could not well identify the lagging and leading relationship with the Guliya δ18O because the linear interpolation also bring some basis.

The UVic Model, a coupled ocean-atmosphere models, could not be used to investigate the response of Guliya temperature to the prescribed North Atlantic SST. The Atmosphere General Circulation Model (AGCM) could perform such simulation. As so far, the model years of running AGCM a day on IBM1600 is about 30–50 year. The computer conditions could complete the simulation proposed by the reviewer so far. In the future, we could try to identify the influence of North Atlantic on Guliya SAT by employing a simple 3-Dimension AGCM on the long-term time scales.

9. Page 1896, L6: ".. demonstrating that the Guliya late-summer precipitation leads the Guliya temperature", Can the authors find justification from the modern observation? What is the mechanism here?

Response: On one-ka time scale, the modern observation is difficult to reveal the leading and lagging links between precipitation and SAT. However, this lagging link between them can physically be described in a climate model. More detailed analyses on mechanisms may be done in the future work.

10. Page 1896, L7-L14: A relationship between North Atlantic SST and the Asian monsoon precipitation was indeed found in some previous studies. However, the precipitation in Fig13 shows anti-phase with NH summer insolation, which is opposite to the monsoon signal recorded in the Chinese stalagmite. Therefore one may wonder whether the previous rule related to monsoon can still be applied to the simulated Guliya precipitation.

Response: The expression that the North Atlantic SST could influence the Asian monsoon is not accurate in the manuscript. The accurate expression is that the North Atlantic SST could influence the summer Asian atmosphere circulation. On the one hand, the influence of Asian atmosphere circulation on the precipitation differs over the different regions, even in the monsoon region (Zhao et al., 2007). On the other hand,

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the north Tibet Plateau is not in the traditional monsoon region (Wang and Ding, 2006; 2008). Therefore, there is no conflict of the anti-phase between the simulated Guliya precipitation and the monsoon signal recorded in the Chinese stalagmite (Wang et al., 2008).

We had rewritten and rearranged the introduction and Section 3 and 5. Some of the minor comments will disappear.

Other concerns:

1. The first paragraph of Introduction is not necessary because it is of no help and only diffuses the main message. By the way, it is not appropriate to call glacial or interglacial stage as "events".

Response: The first paragraph of introduction is removed. The "events" was also removed.

2. P1887, L24: the local monthly

Response: We replaced the words "local the monthly" with "the local monthly" in Line 16–17, Page 4.

3. P1888, 2nd paragraph: The first sentence has no sense. Moreover, for the relationship between astronomical parameters and insolation, one can only refer to Milankovitch 1941 and Berger 1978. The last sentence is not logical, because June insolation at 60N is not necessarily equivalent to June SAT.

Response: The second was rewritten in the modified manuscript. Please see them in the second paragraph in the introduction.

4. P1888, 3rd paragraph: the appearance of SST is too abrupt. It is better to give some explanation on why you want to investigate the relationship between delta 18O and SST, and where and which season.

Response: In the third paragraph of introduction, we proposed the questions that the

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relationship between the Guliya $\delta 18O$ and the ocean-atmosphere system. Then, the appearance of SST in the section 2 would be involuntary.

We focus on the regions in the middle and low latitudes. The season we focus on August–September which the Guliya $\delta 18O$ indicated.

5. P1888 L23: change "cycles" to "distributions", "modulated" to "induced". Change everywhere in the paper "solar insolation" to "insolation" or "incoming solar radiation", and "orbital" to "astronomical".

Response: We changed the words "cycles" and "modulated" to "distributions" and "induced", respectively, and changed the "solar insolation" to "incoming solar radiation" and "orbital" to "astronomical" in whole the manuscript.

L24: change "ultimate" to "most probable"

Response: We changed the word "ultimate" to "most probable" in Line 14, Page 5

L25: delete "millennial-" Response: We deleted the word "millennial- and"

6. P1890:

L15: annual or seasonal temperature?

Response: We added "August–September" in Line 4, Page 9.

L22: change "during" to "between"? "high and low phases" are unclear expressions.

Response: The issues have disappeared in the modified manuscript.

L26: the simulated Guliya temperature

Response: The questions have disappeared in the modified manuscript.

7. P1891:

L2: delete "It is known that"

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Response: The words "It is known that" were deleted.

L3: change "varying earth orbital parameters" to "precession"

Response: The words "varying earth orbital parameters" were replaced with "precession" in Line 22, Page 9.

L4: change "over" to "between"

Response: We changed the word "over" to "between" in Line 1, Page10.

L2-L6 lack logic and more explanation are needed for clarity.

Response: The last sentence was changed to "The Guliya δ18O experienced several approximately 21-ka cycles in the past 130 ka that are directly related to precession (Yao et al., 1997). However, the incoming solar radiation, as a forcing of Guliya δ18O temperature record, differs between the twelve months of the year due to precessional motion (Milankovitch, 1969; Berger, 1978). Thus, we first examine annual cycle of the Guliya incoming solar radiation." Please see them in first paragraph of Section 3.

8. P1891, L10: I guess it is better to replace "dominant" by "the largest"

Response: This issue has disappeared in the modified manuscript. Please check the second paragraph in section 3.

9. The authors have shown that the spectrum of the Guliya delta 18O shows 20.762 precession period, but why do they mention many times 23-ka precession cycle in the delta 18O? Precession has two main periods, 19ka and 23ka (Berger, 1978). On average, 21ka is often used.

Response: We changed the 23-ka with 21-ka in the entire manuscript.

10. P1892:

L4: change "modulated" to "controlled"

Response: The question has disappeared in the modified manuscript.

L5: It is hard to see the obliquity cycle in the simulated temperature in Fig4. Please provide a figure showing the spectrum analysis of the simulated temperature.

Response: Because the precession cycle was more significant than the obliquity cycle. Therefore, we show part of the picture of spectrum analysis in Figure F.

L18: change "generally represents" to "contains"

L19: it seems a broken sentence. "their" means what?

Response: The questions have disappeared in the modified manuscript. Please check the last paragraph in section 3.

L23-L25: Please provide a criterion for defining the periods of warm and cold phases?

Response: According to Fig. 3, we use respectively five highest (11–6, 33–28, 59–54, 83–78, and 105–100 ka BP and lowest (23–18, 45–40, 72–67, 94–89, and 117–112 ka BP; called the cold phase) periods of the August–September Guliya temperature to perform a composite analysis between warm and cold phases.

11. P1890, 2nd and 3rd paragraphs: It is better to give explanations on why these analyses are needed.

Response: We increased some explanations to indicate why the Monte Carlo Simulation and linearly interpolation of Guliya δ18O are needed in Line 2–6, Page 9.

12. More details on the UVic model are welcome. Discussions on its capacity in simulating the climate particularly over the studied region and studied climatic variables (temperature, precipitation, : : :) are also necessary.

Response: We increased the capacity of the UVic Model simulation over NH and China. Please see them in Line 13–14, Page 7.

13. P1891: L14-L16 are logically not understandable.

Response: The sentence was replaced with the new sentence "Because the phase of

the precession cycle of June incoming solar radiation at 60°N is approximately one-quarter phase ahead of that in Guliya δ18O (Yao et al., 1997), the variability of the Guliya δ18O temperature record is possibly synchronous with the variation of the simulated Guliya SAT in the certain month that lags to the June incoming solar radiation". Please see it in the Line 3–7, Page 11.

14. Which SST is used in figure12, summer, annual,: : :?

Response: The SST used in Figure 12 is also in the August–September. We changed the corresponding description in Figure 12. Please see it in Page 27 and 39.

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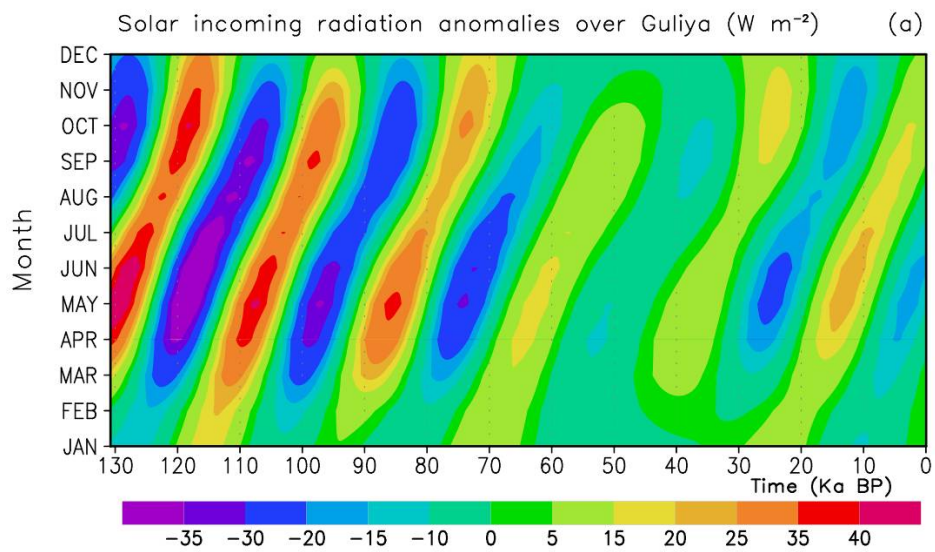
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Thank you very much for your efforts and time on this manuscript again!

Please also note the supplement to this comment:
http://www.clim-past-discuss.net/8/C1155/2012/cpd-8-C1155-2012-supplement.pdf

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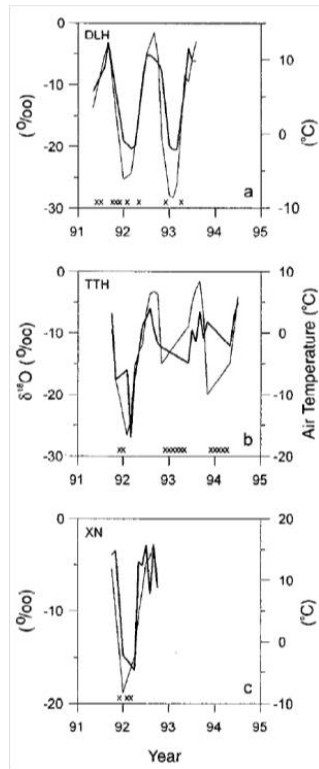Interactive comment on Clim. Past Discuss., 8, 1885, 2012.

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Fig. 1. Fig. A. Annual cycles of incoming solar radiation anomalies over Guliya relative to the mean over the past 130 ka. The abscissa is time before the present, and the ordinate is the month of a year.
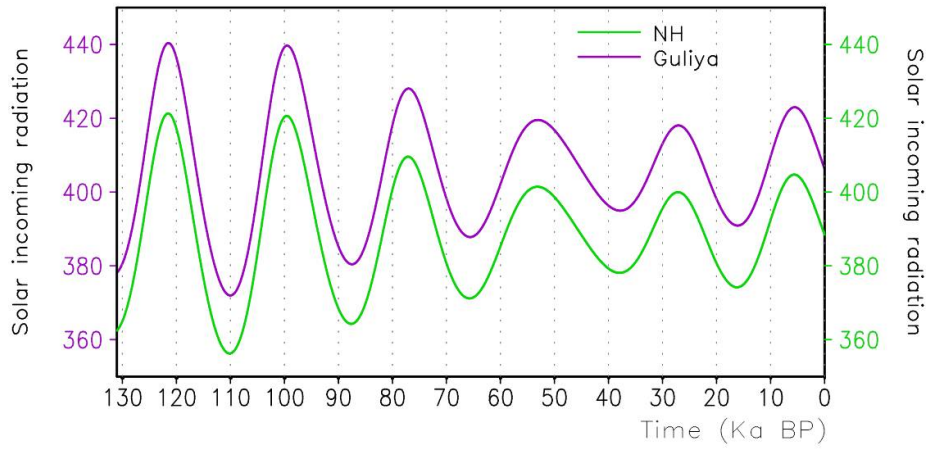
Fig. 2. Fig. B. The monthly averages of δ18O (dark line) and SAT (light line) for individual station (a) Delingha (DLH), (b) Tuotuohe (TTH), and (c) Xining (XN). (Yao et al., 1996)
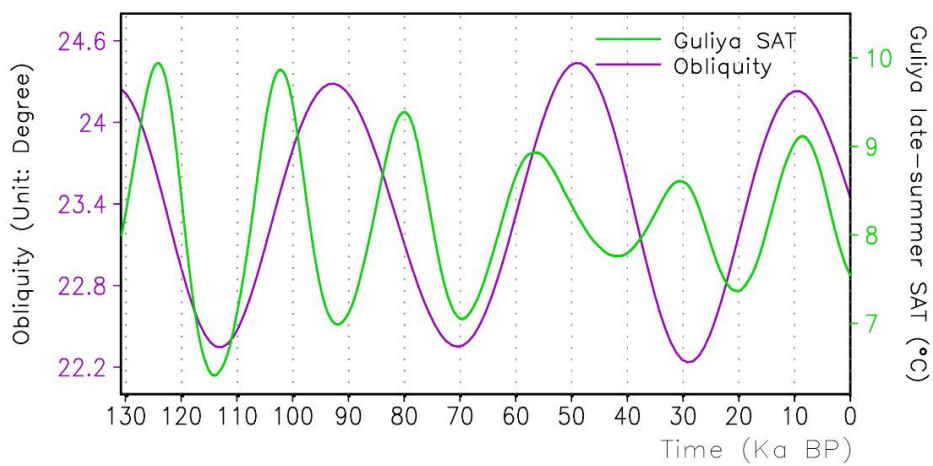
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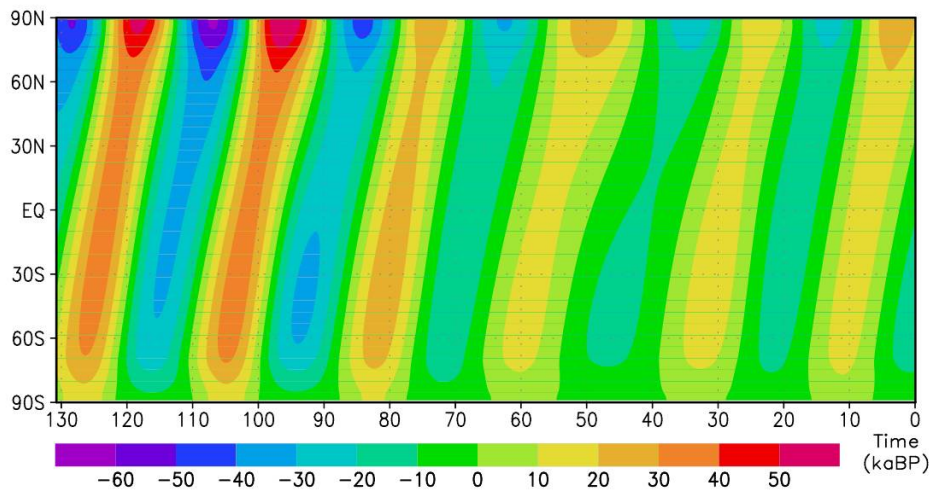
Fig. 3. Fig. C. Zonal anomalies of incoming solar radiation in the August–September over the past 130 ka. The Unit is W m–2.
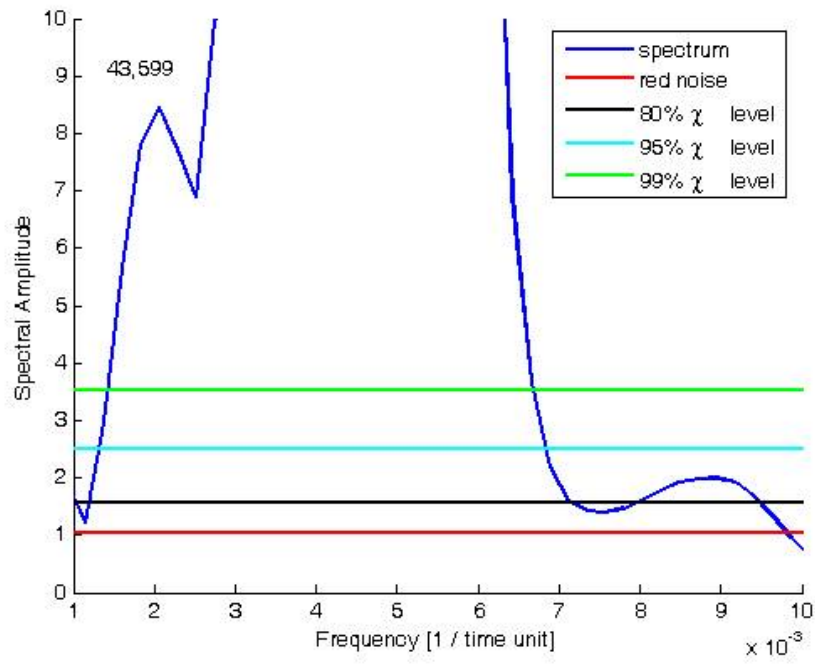
Fig. 4. Fig. D. Incoming solar radiation in the late summer over Guliya (Puple; left ordinate) and NH (Green; right ordinate) during the past 130 ka. The Unit is W m–2.

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Fig. 5. Fig. E. Simulated Guliya August–September SAT (green; right ordinate) and obliquity (purple; left ordinate) in past 130 ka.

Fig. 6. Fig. F. Power spectrum of simulated Guliya August–September SAT.

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