Referee Comments on the paper by Hou et al., Apparent discrepancy of Tibetan ice core δ18O records may be attributed to misinterpretation of chronology, for The Cryosphere Discuss., https://doi.org/10.5194/tc-2018-295.

First, it is certainly good to see the recent interest in our work on the Guliya ice core record that was conducted in the 1990s. The community has come a long way since that time when the greatest challenge that Tandong Yao and I faced when drilling in that part of the world was the question of whether or not it would be possible to drill an ice core at those elevations and then keep it frozen during its transit across the Gobi desert. We didn't know at the time how that work would set the stage for all of those who have come along since those early days.

Regarding the time scales on the early Guliya cores, they raised as many questions as they answered and therefore our team returned to Guliya in 2015 where we successfully recovered 5 ice cores, 4 of which were drilled to bedrock. A recently published paper highlights the geophysical work conducted in the field (Kutuzov *et al.*, 2018). A primary goal of the 2015 drilling campaign was to better constrain the time-scale on the Guliya ice cap by taking advantage of additional, newer analytical approaches and applying them to the freshly drilled ice cores. A number of these analyses are focused specifically on dating the ice and are now underway.

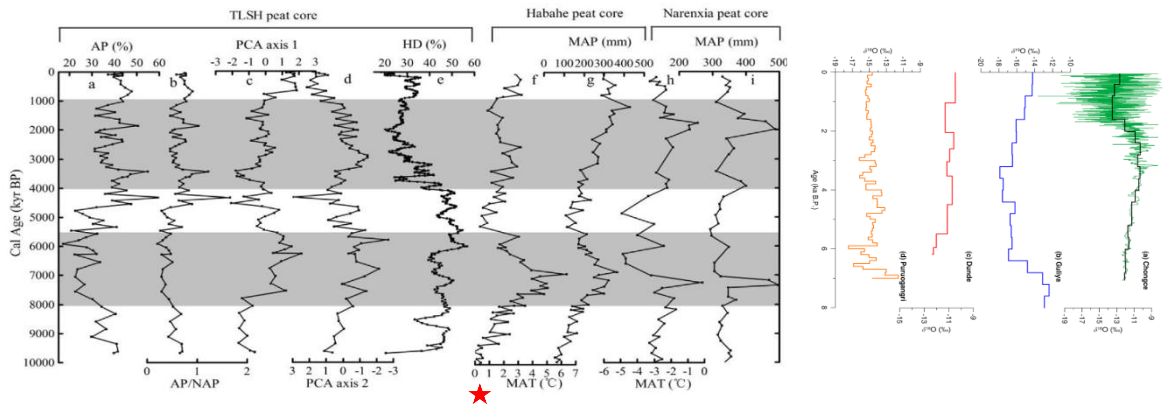
Kutuzov, S., L. G. Thompson, I. Lavrentiev, and L. Tian. 2018. Ice thickness measurements of Guliya ice cap, western Kunlun Mountains (Tibetan Plateau), China, *Journal of Glaciology*, 64(248) 977–989, doi: 10.1017/jog.2018.91.

As an invited referee for the paper by Hou *et al.*, I have addressed a number of the specific issues raised in the manuscript but in short the paper lacks sufficient quantitative support for the authors' conclusions. I hope that the following points will help the authors improve their manuscript.

Specific comments:

Lines 50-55*: "The Guliya record has been widely used as a benchmark for numerous studies since its publication (e.g., Fang et al., 1999; Rahaman et al., 2009; Sun et al., 2012; Hou et al., 2016; Li et al., 2017; Saini et al., 2017; Sanwal et al., 2019). Its stable isotopic record suggests a cooling mid-Holocene based on its decreasing* δ^{18}*O values during that period. However, this cooling mid-Holocene is not found in other Tibetan ice core records available so far."*

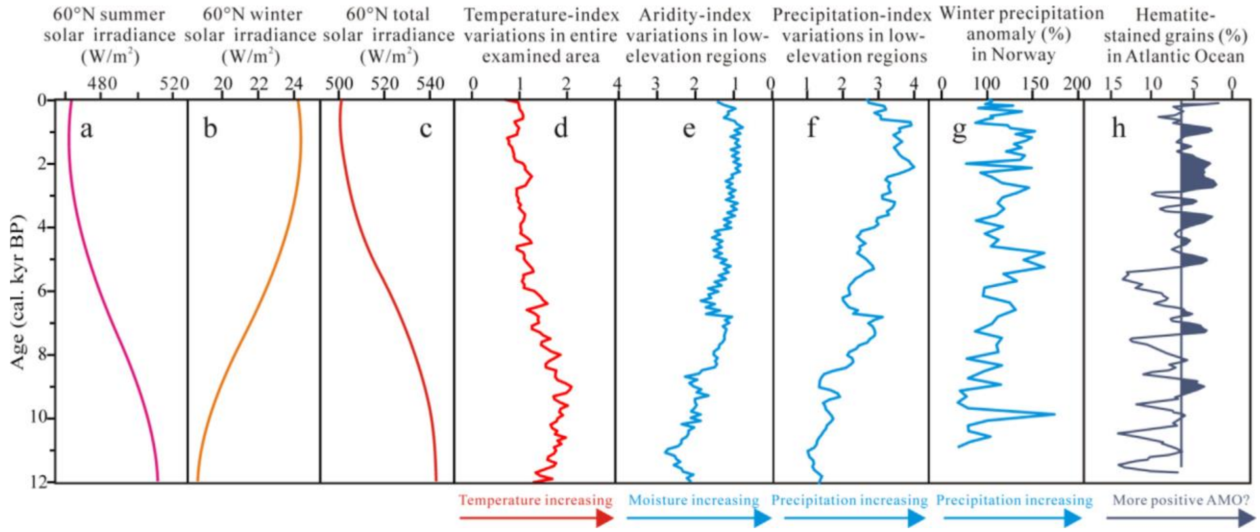
The first sentence will be addressed below. The third sentence is misleading. The mid-Holocene cooling is very noticeable in Tibetan climate records that are not from ice cores. For example, the regional vegetation and climate changes during the Holocene have been reconstructed from a high-resolution pollen record preserved in a peat sequence from the Altai Mountains of Xinjiang, China (Zhang *et al.*, 2018, *Quaternary Science Reviews*, 201, 111-123). These vegetation phases indicate that the regional climate changed from a cold and dry early Holocene to a warmer and wetter early-mid Holocene followed by a cold and dry mid-Holocene, which transitioned to a cool and wet late Holocene with warm and dry conditions characterizing the last millennium. Below is a figure comparing the data in Figure 6 of the Zhang *et al.* paper (left) with Figure 3 (right) from the Hou *et al.* paper. Note that the Guliya δ^{18}O record (blue) is more similar to the mean annual temperature (Figure 6, panel f, red star) than the Chongce $\delta^{18}O$ record. It is also important to note that the Guliya ice core was not used to help establish the chronology of the pollen record.



The figure is a composite of Figure 6 (Zhang *et al.*, 2018) and Figure 3 (Hou *et al*., unpublished).

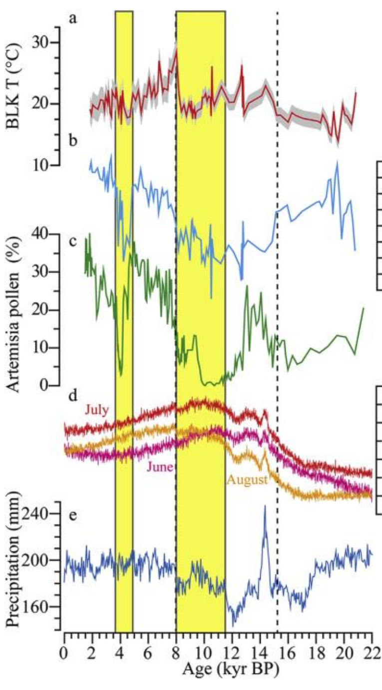
The records above, along with other examples given below, dispute Lines 136-140 *("This warming trend during the mid-Holocene is similar to recent paleoclimatic reconstructions in other parts of the world (Samartin et al., 2017; Marsicek et al., 2018). By comparison, it seems that the $\delta^{18}O$ profile of the Guliya ice core, especially for the period of 6-7 kaBP to ~3 kaBP, is at odds with this warming trend during the mid-Holocene."*). Here the authors are picking records from regions thousands of miles away in much different climate regimes to confirm the Chongce $\delta^{18}O$ record (and time scale). The Samartin *et al*. records are from the Mediterranean while the Marsicek *et al.* records are from Europe and North America. Hou *et al.* (Lines 35-40) state that *"Marsicek et al. (2018) recently presented temperature reconstructions derived from sub-fossil pollen across North America and Europe. These records show a general long-term warming trend for the Holocene until ~2 kaBP (thousand years before present),and records with cooling trends are largely limited to North Atlantic, implying varied regional climate responses to global drivers")*. There are several publications that link North Atlantic climate to the climates of Central Asia and China. Although most of them discuss the linkages between precipitation and westerlies influenced by North Atlantic atmospheric and oceanic processes, papers such as Feng and Hu (2008, *Geophysical Research Letters* 35 doi: 10.1029/2007GL032484) present an argument that North Atlantic SST anomalies strongly affect the TP surface temperature and heat sources, at least in the last century.

There are other records that call into question their conclusions regarding Holocene climate variability as inferred from the Chongce cores. For example, Zhang and Feng (*Earth-Science Reviews*, 2018, 185, 847-869) presented a compilation of pollen records from the Altai Mountains and surrounding regions that show a mid-Holocene cooling trend. Below see their Figure 37 (note panel d) from their synthesis of regional pollen records.



This is Figure 37 from Zhang and Feng, 2018 which was cited above.

Another example that does not support the conclusions drawn from the Chongce ice core is an alkenone-based 21 ka paleotemperature record from Lake Balikun (43.60-43.73ºN, 92.74-92.84ºE, 1570 masl). As shown in the figure below (see panel d), this lake record shows that in this region the peak summer temperature occurred at 8 ka and was followed by general cooling throughout the Holocene.



This is Figure 8 is from Zhao *et al*. 2017 (Contrasting early Holocene temperature variations between monsoonal East Asia and westerly dominated Central Asia. *Quaternary Science Reviews* 178, 14-23).

Warmer conditions for the Early Holocene and cooler temperatures in the mid-Holocene are inferred by additional eastern TP records (see papers cited below). Many of these records are consistent with the Northern Hemisphere summer insolation curve (see panel a in the figure above from Zhang and Feng, 2018).

Shen, J., Liu, X., Wang, S., Ryo, M., 2005. Palaeoclimatic changes in the Qinghai Lake area during the last 18,000 years. *Quaternary International* 136, 131–140.

Yu, X., Zhou, W., Franzen, L.G., Xian, F., Cheng, P., Jull, A.J.T., 2006. High-resolution peat records for Holocene monsoon history in the eastern Tibetan Plateau. *Science in China (Series D)* 49, 615–621.

Herzschuh, U., Kramer, A., Mischke, S., Zhang, C., 2009. Quantitative climate and vegetation trends since the late glacial on the northeastern Tibetan Plateau deduced from Koucha Lake pollen spectra. *Quaternary Research* 71, 162–171.

Zhang, C., Mischke, S., 2009. A Late Glacial and Holocene lake record from the Nianbaoyeze Mountains and inferences of lake, glacier and climate evolution on the eastern Tibetan Plateau. *Quaternary Science Reviews* 28, 1970–1983.

Kramer, A., Herzschuh, U., Mischke, S., Zhang, C., 2010. Holocene tree line shifts and monsoon variability in the Hengduan Mountains (southeastern Tibetan Plateau), implications from palynological investigations. *Palaeogeography, Palaeoclimatology, Palaeoecology* 286, 23–41.

On *Lines 50 - 53* the authors falsely state that "*The Guliya record has been widely used as a benchmark for numerous studies since its publication (e.g., Fang et al., 1999; Rahaman et al., 2009; Sun et al., 2012; Hou et al., 2016; Li et al., 2017; Saini et al., 2017; Sanwal et al., 2019).*

Returning to Lines 50-54, The definition of "benchmark" is a point of reference from which measurements may be made. In none of the references cited above are the time series constructed to match that of Guliya. Those chronologies were independently developed. Therefore the suggestion that the Guliya record misled the development of the climate records in these or any other papers is false. This sentence should be rephrased as "The Guliya record has been compared with climate records from numerous studies…..”). The records in these and other references were broadly compared to the Guliya record. If the climate records from these independently dated records match the Guliya record then it is not because they *were matched to* Guliya in order to develop their chronologies, it is because their independent chronologies were coherent with the Guliya chronologies. Also, if the Holocene temperature records presented in these publications are similar to Guliya's Holocene $\delta^{18}O$ (temperature) time series, which contradicts the Chongce $\delta^{18}O$ (temperature) record, it raises a serious challenge to the validity of the interpretation of the Chongce records, which the authors should address.

Hou *et al.* make statements that are inconsistent with existing evidence. For example they state (Line 179-181): "*This would also cast doubt on the notion of asynchronous glaciation on the TP on Milankovitch timescales (Thompson et al., 2005), which is developed based on the original chronology of the Guliya ice core.”*
Guliya is not the solitary piece of evidence supporting asynchronous glaciation on the Tibetan Plateau. There are a number of exposure dates that also point to asynchronous glaciation. Owen *et al.* (2008, Quaternary glaciation of the Himalayan-Tibetan orogeny in *J. Quaternary Science* 23, 513-531) state in their abstract "Glaciers throughout monsoon-influenced Tibet, the Himalaya and the Transhimalaya are likely synchronous both with climate change resulting from

oscillations in the South Asian monsoon and with Northern Hemisphere cooling cycles. In contrast, glaciers in Pamir in the far western regions of the Himalayan–Tibet orogen advanced asynchronously relative to the other regions that are monsoon-influenced regions and appear to be mainly in phase with the Northern Hemisphere cooling cycles."

Lines 182-184: *Recently, Ritterbusch et al. (2018) applied 81Kr dating, with the updated laser-based detection method of Atom Trap Trace Analysis (ATTA), to the bottom ice samples collected at the terminal of the Guliya ice cap. The resulting 81Kr ages are <50 kaBP.* ^{81}Kr ages on the <u>margin</u> of the Guliya ice cap tell us nothing about the age of the bottom ice of the 308m ice core at the Plateau "Site 2" drill site (where the 1992 core was drilled). Ice samples collected in 2015 for ^{81}Kr analyses were collected down the flowline and in close proximity to our 1992 Site 1 drill (see locations in Figure 1 of Thompson *et al.*, 1995, *Annals of Glaciology*). In 1992 the first Guliya core "Site 1" was drilled to 92.2 meters, at which point we terminated drilling because we found an unconformity in the ice layers 83 meters below the surface (see discussion on page 176 in the aforementioned Thompson *et al.* 1995 paper). Thus, there is no reason to believe there is a time stratigraphic linkage between the bottom ice along the margin (near the camp, see aforementioned map) and the ice at the bottom of our deep core drilled on the Plateau at Site 2 (see map).

Minor points

Some statements are erroneous or misleading and need to be checked and verified. For example, on *Lines 128-130 they state: "However, this high δ^{18}O value is not observed around the depth of ~211 m in the Puruogangri depth δ18O profile (Fig. 2). Indeed, all δ18O values in the depth profile of the Puruogangri core are well below -12‰. Therefore, the high δ^{18}O value around ~7 kaBP of the Puruogangri core (Fig. 3) needs further verification."* Those values exist in the raw data around 211 meters (the raw data below are ~ 6.9-7.0 ka), and this high δ^{18}O value is a function of the time averaging (100 yr averages), whereas the authors are basing their observations on one meter averages, which incorporate ~30 data points).

Depth (m)	δ^{18}O (‰)
210.960	-11.35
210.990	-11.30
211.025	-12.12

Finally, the authors' failed to mention that evidence exists suggesting that Chongce may be a surging glacier. In 1991 Chinese scientists published a Quaternary Glacial Distribution Map of the Tibetan Plateau. According to this map, the terminal moraines around the Guliya ice cap are very close to their maximum position during the last two glaciations. However, this is not the case for the Chongce ice cap which shows the greatest variations in ice extent of any of the ice caps in this region. In addition, the Chongce glacier, which flows from the Chongce ice cap, surged between 1992 and 2014 while the Guliya ice cap remained static (Yasuda and Furuya, 2015; Fig. 3). Therefore, it might be inaccurate to assume that the timescale developed for the Chongce cores should reflect that of Guliya. In light of the geophysical considerations discussed above it is premature to conclude that the Chongce results invalidate the much longer Guliya timescale.

Yasuda, T. and Furuya, M. 2015. Dynamics of surge-type glaciers in West Kunlun Shan, Northwestern Tibet. *Journal of Geophysical Research - Earth Surface*, https://doi.org/10.1002/2015JF003511.

Note to readers of this review:
When asked by Editor Carlos Martin to serve as a referee for this paper, I inquired whether this would constitute a conflict of interest as our Guliya record is a major subject of the paper. I was told "My view is that there is no conflict of interest". Therefore, I opted to serve as a referee.