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Interactive comment on "Environmental dynamics since the last glacial in arid Central Asia: evidence from grain size distribution and magnetic properties of loess from the Ili Valley, western China" *by* Yue Li et al.

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Linguistic issues:

CS: Lines 37-42: A lack of correlation between EM1 proportions and GISP δ18O values at the millennial scale, combined with modern weather data, suggests that Arctic polar front predominates in the Ili Basin and the Kyrgyz Tian Shan piedmont during cold phases, which leads to the dust transport and accumulation of loess deposits, while the shift of mid-latitude westerlies towards the south and north controls the patterns of

precipitation/moisture variations in this region. Reviewer's note: a lack of correlation between A and B means C was dominant? It implies that there are no other possibilities (D, E, . . .). Even worse, is "while the shift of the mid-latitude westerlies . . . controls patterns of precipitation/moisture . . ." corresponding to or with"shift of the Arctic polar front controls the temperature patterns of wind strength"? If so, you have to say so.

AR: Thanks for your critical comments. The logic of the abstract was unclear, and it is unreasonable to draw conclusions beyond the information available in the data. We have now tried to clear the confused logic, and rewritten the Abstract and Conclusions sections in this manuscript. It is important to note that Central Asia is very large and consequently it is reasonable to assume that different climate subsystems act upon different parts of the region. Therefore, observations made at one end of Central Asia (e.g. Tajikistan) do not necessarily apply to the other (e.g. Ili Basin). Furthermore, the Ili Basin itself is almost 1000km across and is geographically diverse, and it is reasonable to assume that the western part of the basin, e.g. the published site of Remizovka, is more exposed to influences such as the polar northerlies than sites in the eastern part of the basin, e.g. NLK presented here, which are much more sheltered by the high Tien Shan mountains. Tajikistan is mainly impacted by the westerlies, and the North Atlantic climatic signals are presented in Tajikistan loess, which implies that the westerlies linking the North Atlantic and the Eurasia loess, can influence accumulation of loess deposits in Tajikistan (Vandenberghe et al., 2006). A lack of correlation between EM1 proportions and GISP δ18O values at the millennial scale only indicates that other climate systems control the wind dynamics responsible for dust transport and the accumulation of loess during cold phases in NLK, rather than the Westerlies. Thus, we cannot conclude that "Arctic polar front predominates in the Ili Basin and the Kyrgyz Tian Shan piedmont during cold phases." We have rewritten this sentence, like this "The dominance of the Siberian high-pressure system at NLK in eastern Central Asia contrasts with the influence of the mid-latitude westerlies in southwest Central Asia, as demonstrated by good correspondence between grain size and GISP δ18O at Darai Kalon, Tajikistan." We have deleted the unreasonable suggestion that the shift of mid-latitude westerlies towards the south and north controls the patterns of precipitation/moisture variations in Central Asia. We added some records from modern and Holocene climate change records to substantiate our arguments for mid-Westerlies changes. Actually, those records demonstrated that the mid-latitude Westerlies truly controlled the patterns of moisture variations in Arid Central Asia (ACA) (Li et al., 2011; Huang et al., 2015; Cai et al., 2017). However, we can't draw that conclusion from "A lack of correlation between EM1 proportions and GISP δ18O values at the millennial scale". "while the shift of the mid-latitude westerlies . . . controls patterns of precipitation/moisture . . ." isn't corresponding to or with "shift of the Arctic polar front controls the temperature patterns of wind strength". Available data enable us to compare our data from the eastern, sheltered end of the Ili Basin with the more exposed Remizovka section at the southwestern margins of the basin – with respect to likely climatic influence and its impact on grain size. Remisowka (Machalett et al., 2008) is located along the northern piedmont of Tianshan Mountains (Fig. 1a in manuscript). Because NLK is much more sheltered from northerly weather systems than Remisowka, there is a good chance that the polar front had more of an influence on Remisowka than on NLK. In addition, based on modern and Holocene climate data, we argue that the Siberian High may have exerted a significant influence on wind dynamics in the Ili Basin, leading to dust transport and the accumulation of loess during cold phases in NLK. Thus we argue that the Siberian High controls wind strength and mid-latitude westerlies control precipitation/moisture. A strengthened Siberian High would push the mid-latitude Westerlies pathways further to the south, resulting in comparably drier conditions in the northern Central Asia regions (e.g. Tianshan Mountains) but wetter conditions in south-western Central Asia (Pamir) (Lei et al., 2014; Wolff et al., 2017). Intensity and geographical position of the Siberian High can strongly control precipitation and atmospheric circulation patterns (meridional or zonal) at mid-latitudes of Asia (Panagiotopoulos et al., 2005). The coupling of the Siberian High with the mid-latitude Westerlies system likely contributed significantly to the climate variability in the study area. We have modified our text to explain these drivers more clearly.

CS: Lines 42-44: Comparison of EM1 proportions with Northern Hemisphere summer insolation clearly illustrates local insolation-based control on wind dynamics in the region, and humidity can also influence grain size of loess over MIS3 in particular. Reviewer's note: to me (this reviewer), the logic relationship between these two sentences are not traceable at all. "local insolation-based control on wind dynamics": what does this mean?

AR: We have clarified our expression. In Fig. 7, we can see the consistent variation trend between EM1 proportions and summer insolation, which illustrated the great influences of insolation on the grain size, i.e. wind dynamics. EM1 proportions appear to correlate well with Northern Hemisphere summer insolation. We used June insolation at 45°N in this paper since the latitude is similar to that of NLK section. Thus we changed the term "local insolation" to "summer insolation at 45°N" / "regional insolation variation" in the manuscript in order to avoid misunderstanding. The grain-size variations over MIS 3 don't correspond to the trend of summer insolation, however. Since moisture availability is the dominant factor controlling glacier growth in Central Asia, we attributed that to influences of humidity on vegetation growth in source areas and further availability of source sediment. Consequently, we rewrote this sentence, like this "On orbital timescales, comparison of EM1 proportions with Northern Hemisphere summer insolation at 45°N strongly suggests control of summer insolation on wind dynamics in the region. Out of phase peaks in loess deposition and glacial expansion in the region demonstrate the importance of moisture availability on loess deposition in MIS3 in particular."

CS: Lines 55-60: The relative influence and intensity of these major climate subsystems have varied across the latitudinal and longitudinal range of Central Asia through time. Thus identification of the predominant climate regimes in a certain region is a crucial precondition for tracing paleoclimatic evolution. Reviewer's note: (1) relative influence? Maybe relative importance. (2) The first sentence continues its SPECIFIC tone (i.e., Central Asian), but the second sentence turns to a general tone (i.e., a certain region). To me (this reviewer), it is misleading.

AR: (1) We have clarified this distinction in the text, and substituted “relative influence” with “relative importance”. (2) We cannot use a specific concept to represent a general concept. It is indeed misleading. We have changed the second sentence to “Thus identification of the predominant climate regimes in this region, using geological archives, is a crucial precondition for tracing paleoclimatic evolution.”

CS: Lines 66-72: While loess in Central Asia has (. . .. . .) increasingly formed the focus of loess research, as yet the forcing mechanisms and the climatic conditions responsible for loess-paleosol sequences formation are ambiguous, and the paleoclimatic evolution recorded by these loess deposits in this region is not systematically understood. Reviewer’s note: to me (this reviewer), “increasingly formed the focus”, “the forcing mechanisms . . . are ambiguous”, and “not systematically understood” are all belong to“expression inadequacies”.

AR: Here, we have simplified the language and made the purpose of this paper much clearer and better to understand. We also added three citations in an effort to reinforce the lack of systematic understanding of the forcing mechanisms and the climatic conditions responsible for loess-paleosol sequences formation.

CS: Lines 78-81: Climatic teleconnections, especially between the North Atlantic and East Asian Monsoon regions, are likely to have been recorded within the Central Asian loess. As yet, however, the region so far largely lacks data by which the role and contribution of the central parts of the Eurasian continent, as an environmental bridge, can be elucidated. Reviewer’s note: to me (this reviewer), there is a logic gap in this statement. I mean that you (authors) may have to bring the environmental bridge to the front so that the importance of Central Asia in documenting the teleconnections is pronounced first.

AR: Thanks for your suggestion. We have clarified the language in the text and the wording of our arguments. Since we know basically nothing about millennial-scale

climatic changes in Central Asia, our aim is to investigate a loess section in Central Asia to see to what degree climatic teleconnections exist between North Atlantic and East Asia first, i.e. the first step is to generate data. Therefore, we have made the aim clearer, like this “Data for Central Asian loess are so far lacking at this resolution, despite its strategic location as a likely environmental bridge between the North Atlantic and East Asian Monsoon regions.” We deleted the sentence “Climatic teleconnections, especially between the North Atlantic and East Asian Monsoon regions, are likely to have been recorded within the Central Asian loess.”

CS: Other suggestions Magnetic Susceptibility 1.1. “Low susceptibility in paleosols and high susceptibility in loess units” were sufficiently documented in Alaskan loess and in Siberian loess and Professor Liu Xiuming is a leading scientist on this. Please see if his works and propositions can help you. 1.2. The coarse particle-association of high susceptibility can be tested simply by measuring the susceptibility of different particle size fractions. This can be done on selected samples and the data of the selected samples may elevate your confidence of interpretation. 1.3. If I were the author, I would have completely excluded susceptibility portion from this paper and may (just may) write a separate paper on magnetic susceptibility.

AR: The relationship between pedogenesis and magnetic susceptibility in the higher-latitude loess deposits of Alaska and Siberia is different from the Chinese Loess Plateau loess as suggested by Liu et al. (1999) and Liu et al. (2008). At NLK, lower susceptibility exists in paleosols and higher susceptibility in loess units. Although this scenario is difficult to explain fully through variation in wind strength alone, it showed that wind strength, or wind dynamics, would influence MS variations at least and thus paleoclimatic reconstruction using climatic proxies, such as MS. Thus it is necessary to understand the atmospheric dynamic pattern during loess deposition further. Consistently low χfdUnderstanding the mechanisms for the enhancement of magnetic susceptibility is beyond the scope of this study. We only intended to illustrate the significant impacts of wind dynamic on MS. In addition, ferromagnetic minerals, including magnetite and hematite, belong to heavy minerals which have higher relative density. Thus when wind becomes stronger, more ferromagnetic minerals will be transported to deposition areas, resulting to higher MS values. Thus we have modified the subtitle 5.1, like this "Impacts of wind dynamics on magnetic susceptibility variations".

CS: Particle Size 2.1. You need a comprehensive and streamlined review on existing literature dealing with interpretation of loess particle size. The literature review can be either "school division-based" or time-based (earlier time and later time) or country based (west and China). 2.2. After the expected review is properly done, you may delete those insignificant references (I mean that you cited too many and that many of them may be insignificant). 2.3. Since you heavily rely on Vandenburghe (2013) for EM1, EM2, and EM3 arguments, you are strongly suggested to provide a complete and concise re-statement of Vandenburghe (2013) in debating pros and cons of EM1, EM2, and EM3 for representing aolian dynamics. If he was so sure and nobody else was at his odd, your application of EM1, EM2, and EM3 to interpreting aolian dynamics may be more acceptable. If his argument was case-dependent, you have a harder task to establish your case though. 2.4. I am wondering if the cumulative particle-size curve does show a statistically meaningful break between EM1 and EM2 and also a break between EM3 and EM2? If it does not, should your reliance on Vandenburghe (2013) be questionable? What I try to say is: if you can confidently justify the acceptance of EM1, EM2, and EM3 for representing aolian dynamics, you do have a case here. Otherwise, your opponents can always argue that: those coarse particles may have indeed locally sourced, but those fine particles can either be remotely (high-elevation) sourced or locally (near-surface) sourced.

AR: Thanks for your suggestions. In the section 5.2, we have summarized the significance of grain-size analysis. Relevant studies were separated into two groups according to the unmixing method of grain size spectra. Vandenberghe (2013) applied visual inspection of grain-size distribution curves and the EMMA end-member analysis in combination to define the characteristic grain-size distribution of primary loess

deposits and review their respective processes and conditions of transports and deposition, relying largely on loess samples from central and eastern Asia and northwestern and central Europe. Thus his argument was based on a large number of previous studies from a range of sites, and is not case-dependent. For example, the subgroup 1.b.2 in Vandenberghe (2013) has also been identified in the loess of Chinese Loess Plateau, southern, northwestern and central Europe. Furthermore, in the studies of loess sediments from the Qilian Mountain region, Rasmussen et al. (2014), Nottebaum et al. (2015) and Yang et al. (2016) have interpreted the multiple sources of loess sediments and dynamic conditions according to sediment groups in Vandenberghe (2013). We have included those arguments in the main text. EM1 and EM2 of our results have modal grain size approximately corresponding to the 'subgroup 1.b.1' and 'subgroup 1.b.2' respectively. Vandenberghe (2013) suggested that although component 1.b.1 and 1.b.2 occur jointly together in the proximal depositional regions, they are clearly distinct from each other in terms of the coverage and transportation distance. In Fig. 4 of manuscript, the mirror image relationships over millennial scales can be observed, which may implied that both EM1 and EM2 have a same origin, but wind strength controlled the relative proportions of both through time. In addition, grain-size distributions of modern dust illustrate a modal grain size of 33.3 μm in winter and 44.6 μm in summer in the northern and western Chinese Loess Plateau (Sun et al., 2003) (Fig. 1). These modes are similar to EM2 and EM1 in our results, respectively. It is generally assumed that vegetation coverage is more extensive in summer than in winter in CLP. Therefore, availability of sediments in source areas wouldn't influence the grain sizes, conversely differences in wind dynamic between these two seasons likely play an important role in controlling the grain sizes. While EM3 ("subgroup 1.c.1") indicated a different aerodynamic environment from EM2. The former would settle when the wind velocity decreases and even stops, as suggested by Lin et al. (2016), but the latter were interpreted as transportation during cyclonal dust storm outbreaks (Vandenberghe, 2013). Consequently, the cumulative particle-size curve can give a statistically meaningful break between EM1 and EM2 and also a break between EM3 and EM2. Actually, greater dispute exists in the origin of the EM3 size fraction. In the manuscript, we suggest that the fine-grained EM3 (c. 18.9 μm) is the result of background loess supply in the Ili Basin, and infer the EM3 modal peak to derive from low altitude non-dust storm processes after excluding the aggregate model, transportation by high-altitude westerlies and influences of post-depositional processes. Therefore, those fine particles are also likely to be locally (near-surface) sourced.

CS: Questions for 5.3 Aeolian dust dynamics in eastern Central Asia: links to atmospheric systems Lines 440-447: Central Asia is variably influenced by the Asian monsoon from the south (Dettman et al., 2001; Cheng et al., 2012), the mid-latitude westerlies (Vandenberghe et al., 2006), the Siberian high-pressure systems from the northeast (Youn et al., 2014), and the polar front from the north (Machalett et al., 2008). However, by virtue of its geographical position, most of these climate influences can be excluded for the Ili Valley since it is sheltered to the northeast, east and south. The Asian high mountains largely inhibit the intrusion of Asian (Indian and East Asian) monsoons to the region, and the influence of the Siberian High (An, 2000) has been shown to decrease westward from the CLP (Vandenberghe et al., 2006). Reviewer's note: Downplaying Asian monsoons may be acceptable since the Yili Valley is indeed blocked by the Tianshan Mountains on the south. But, downplaying Siberian high-pressure system (SibH) is not well justified. Yes, SibH is weakening away from its center, but you cannot say that the Yili Valley was beyond the SibH influence. Furthermore, your favored "polar front" is actually also blocked by high mountains on the north. If polar front was indeed the major player, you may have to provide modern climate backgrounds in which strong polar front interacted with the prevailing westerly flow to stimulate dust storms in the Yili Valley.

AR: Thanks for your good suggestions. We have collected some modern and Holocene records about atmospheric circulation in central Asia over the past month. Available data enable us to compare our data from the eastern, sheltered end of the Ili Basin with the Remizovka section at the southwestern margins of the basin – with respect

to likely climatic influence and its impact on grain size. Remisowka (Machalett et al., 2008) is located along the northern piedmont of Tianshan Mountains (Fig. 1a in manuscript). Because NLK site is much more sheltered from northerly weather systems than Remisowka, there is a good chance that the polar front had more of an influence on Remisowka than on NLK. While in the north/northeast of our study area is a massive cold high âĂŢ Siberian High. The Siberian High is the most dominant Northern Hemisphere anticyclone and is centered between 40°N and 65°N, 80°E and 120°E (cf. Fig. 3 in Huang et al. (2011)), and its anticyclonic feature is broadly recognized as the dominant mode of winter and spring climate over Eurasia (Sahsamanoglou et al., 1991; Savelieva et al., 2000; Gong and Ho, 2002; Panagiotopoulos et al., 2005). In addition, based on modern and Holocene climate data, we argue that the Siberian High may have exerted a significant influence on wind dynamics in the Ili Basin, leading to dust transport and the accumulation of loess during cold phases in NLK. In addition, modern meteorological data show that the maximum wind at NLK mainly blows from the west, and that dust storm development in Ili river valley is closely linked with southward-moving high-latitude air masses, while the air masses can enter into the Ili Basin round the northern Tianshan (see the Supplementary materials and Ye et al. (2003)). Therefore, the Siberian high-pressure system is able to influence the Ili Basin, and the southward-moving high-latitude air masses associated with it can enter into the Ili Basin, leading to dust transport and the accumulation of loess deposits during cold phases in NLK. We have rewritten the section 5.3. Please see Lines 449-475 in the manuscript and Supplementary materials.

CS: Lines 448-456: Modern satellite data indicates that dust storm development in Ili river valley is closely linked with southward-moving high-latitude air masses (Ye et al., 2003). Karger et al. (2016) provided a detailed picture of the westerlies for the Ili Basin, in which a rain belt gradually migrated towards the south and north in autumn and summer, respectively. According to this scenario, enhanced evaporation coupled with strengthened westerly winds would bring more humid and warm air masses to Arid Central Asia (ACA) during the Holocene (Zhang et al., 2016). Therefore, based on our grain-size observations, we argue that the Arctic polar front, intruding southward in the winter and retracting northward in summer (Machalett et al., 2008), most likely increased the frequency and strength of cyclonic storms, leading to dust transport and the accumulation of loess deposits during cold phases when it predominated in the Ili Basin and along the Kyrgyz Tian Shan piedmont. Reviewer's note: I (this reviewer) failed to see the linkage between "souward-moving high-latitude air masses" and "migrated rain belt". I also failed to see the linkage between "enhanced evaporation" and"strengthened westerly winds". Consequently, I failed to see the logic of your reasoning: the Arctic polar front, intruding southward in the winter and retracting northward in summer (Machalett et al., 2008), most likely increased the frequency and strength of cyclonic storms during cold phases. At least, you have to say more about the logic of your reasoning.

AR: In this respect our logic was flawed. We have clarified the logic of our arguments in the text. As mentioned above, it is unreasonable to draw conclusions beyond the information available in the data. Therefore, we reconsidered the atmospheric system responsible for aeolian dust dynamics in our study area, and then rewrote and rearranged the paragraphs. As explained above, the Siberian high-pressure systems exerted a significant influence on wind dynamics responsible for dust transport and the accumulation of loess deposits during cold phases in NLK, and the mid-latitude Westerlies controlled the patterns of moisture variations in Arid Central Asia (ACA), based on modern and Holocene climate data. A strengthened Siberian High would push the mid-latitude Westerlies pathways further to the south, which resulted in comparably drier conditions in the northern Central Asia regions (e.g. Tianshan Mountains) but wetter conditions in south-western Central Asia (Pamir) (Lei et al., 2014; Wolff et al., 2017). Intensity and geographical position of the Siberian High can strongly control precipitation and atmospheric circulation patterns (meridional or zonal) at mid-latitudes of Asia (Panagiotopoulos et al., 2005). Therefore, the coupling of the Siberian High with the mid-latitude Westerlies system likely contributed significantly to the climate variability in the study area, which may interpret the seesaw relationship during MIS3

shown in Fig. 7 of manuscript.

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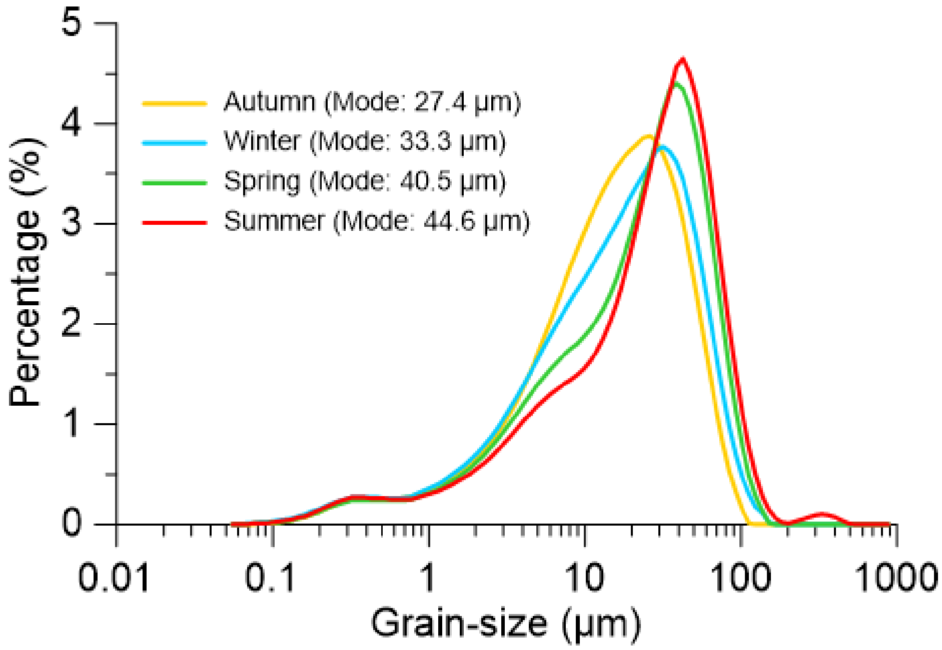

Fig. 1. Grain-size distributions of seasonal dusts in the northern and western CLP (Huanxian)