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Climate of the Past Discussions

Interactive comment on "A major reorganization of Asian climate regime by the early Miocene" *by* Z. T. Guo et al.

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First of all, we would like to express our sincerest thanks to Drs. William Ruddiman, Gille Ramstein, Denis Rousseau and an anonymous referee for the highly constructive reviews and suggestions. The comments are not only helpful for improving the current manuscript, but also provide valuable insights for future studies on the relevant topics. Consequently, they have been fully considered in the revised version of the manuscript. Any further comments and suggestions will be highly appreciated.

Reply to the comments from Dr. Ruddiman

Dr. Ruddiman suggested adding a few sentences to more clearly explain the typical ‘planetary’ pattern of subsidence of dry air in the subtropics over land masses in the downward limb of the Hadley Cell, and the different causes of aridity between the North American deserts and other subtropical deserts. These have been done in the revised version in adding a paragraph. Except for the North American deserts that are primarily the result of rain-shadow development in the lee of mountains, most low-latitude aridity results from subtropical high pressure zones related to the descending branches of the Hadley Cells near the equator and the Ferrell Cells at mid-latitudes over both the hemispheres. The subsiding air of the subtropical highs adiabatically warms, causes the air to dry out, and inhibit condensation, leading to dry conditions on the underlying continents.

Dr. Ruddiman suggested adding a figure that shows the effect of tectonic uplift and seaway withdrawal in changing Asian climate toward wetter or drier, particularly the simulated summer and winter changes for each of the two types of tectonic changes, and compare with the paleoclimatic indicators mapped in Fig. 3 and 4. A 6-panel new figure has been added (Fig. 11) in the revised version. Correspondent text has been added in Section 5 to discuss the data-model consistencies with regards to the summer/winter circulations and precipitation fields.

All the other issues raised by Dr. Ruddiman have also been fully considered in the revised version. These include:

- The effect of the relative duration of the summer and winter monsoons in determining soil type: this has been more clearly explained. We also explained that the substantially increased amount of illuvial features in the Miocene soils indicates much more abundant rainfall in northern China during the early Miocene than for the Quaternary.

- A misleading phrase in the discussion version, "permanent ice sheets in the northern Hemisphere only appeared since the late Miocene, 10-6 Ma": The phrase has been revised. This issue has also been raised in Dr. Rousseau’s comments. We agree that impermanent ice of a modest size, probably mainly mountain and piedmont glaciers in the Northern Hemisphere, only appeared since the late Miocene, ˜10-6 Ma according to the available paleoclimate data, especially the ice-rafting data from the

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circum-Arctic regions.

- Adding other relevant long timeseries in Fig. 5 of the CPD version: A pollen sequence from the Qaidan Basin (Wang et al., 1999) has been added. All the used timeseries about regional climate have been grouped into Fig. 10 of the revised version. Although some other sequences are available, they seem not to be directly related with the discussed changes.

- Revision of the caption of Fig. 8: The caption has been revised.

- Improvement of English: We express our deep thanks to Dr. Ruddiman for the further scientific comments/suggestions, as well as the helps for language improvements.

Reply to the comments of Dr. Ramstein

Dr. Ramstein requested to clarify the significance of the late Oligocene map (Fig. 3e), which doesn’t show a clear pattern of monsoon-dominant climate, on the timing of the major climate reorganization. This has been more clearly explained in the revised version. The main support for a ~22-25 Ma timing of the major re-organization consists of three lines of evidence. Firstly, the available Miocene loess-soil sequences dated by geomagnetic methods, as demonstrated in Section 3, consistently indicate that this major change occurred by (no-latter than) 22 Ma ago. Secondly, the early and middle Oligocene maps show a zonal pattern corresponding to a planetary circulation system while the late Oligocene pattern is not clearly defined because of a lack of data in southern China, probably due to tectonic movements and large-scale erosions. A typical monsoon dominated pattern is clearly definable since the early Miocene, implying that the transition occurred within an interval from the late Oligocene to 22 Ma ago. Thirdly, some other geological sequences summarized in Section 4 consistently indicate a climate transition at ~20-25 Ma. These three lines of evidence suggest a chronological constrain of the transition for an interval from 25 to 22 Ma.

One of the main suggestions from Dr. Ramstein is to reinforce the discussions of the

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stimulated circulation patterns relative to the tectonic changes and compared with the results derived from the Miocene loess-soil sequences and the paleoenvironmental maps. This is also in line with the suggestion of Dr. Ruddiman about adding a new figure to demonstrate the simulated summer and winter circulations and the consistencies with the geological records. These have been considered through adding a new figure and relevant paragraphs in the revised version. The effects of Tibetan uplift and Paratethys retreat on the seasonal circulation patterns are roughly similar for northern China. In summer, both factors deepen the Asian low-pressure and lead to the south-to-north inflow in China that brings moisture. In winter, they intensify the Asian high-pressure and lead to northwesterly winds in northern China that pick up eolian dust from the inland deserts in Asia. These are mostly consistent with the seasonal circulation patterns indicated by the Miocene loess-soil sequences (Section 3) and the Neogene environmental maps (Section 2). The combined effect of the two main tectonic changes has been clearly reproduced in the numerical experiments and consistent with the climate patterns showed by geological indicators (Section 2).

Dr. Ramstein suggested a discussion based on the modeling results on why the monsoon-dominant pattern and inland deserts have been constantly maintained in the past 22 Ma. This has been addressed in the revised version. The fact that monsoon-dominant climate and inland deserts were formed by 22 Ma ago provides an independent perspective that these tectonic conditions had evolved to a threshold by that time sufficient to cause the major climate reorganization. Sensitivity experiments indicate that further Plateau uplift and withdrawal of the Paratethys Sea enhance both the summer and winter monsoon and inland aridity as well explains the stability of the monsoon-dominant pattern and inland deserts in the past 22 Ma. Our results also indicate that ice volume changes, as shown by the marine oxygen isotope records (Zachos et al., 2001), had not rearranged the basic climate pattern in Asia. Dr. Ramstein also suggested adding some discussions on if there were any relationships between the global atmospheric CO2 changes and the climate reorganization in Asia. This is a highly interesting issue and has been addressed in the revised manuscript in adding two panels in Fig. 5. Firstly, Proxy estimates (Perason and Palmer, 2000; Pagani et al., 2005) suggested large CO2 decreases at ˜50 Ma, 30 Ma and 24 Ma (Fig. 5b and 5c). Although the fall at ˜ 24 Ma is close in time to the Asian climate change, changes in CO2 level are not likely by themselves be the main cause of the climate-pattern rearrangement. Consequently, regional factors must have played a dominant role. Secondly, we also discussed in the revised version that accurate pale-CO2 estimates have the potential to provide insights on the timing of major tectonic uplifts as Tectonic uplift may have major impacts on atmospheric CO2 levels by accelerating chemical weathering and increasing the burial of organic matter.

Dr. Ramstein suggested adding a discussion on the potentials of the recently developed paleo-altmetry approaches in the reconstruction of the elevation history of the Himalayan-Tibetan complex, and to discuss the different climate impacts based on the available numerical experiments. These have been discussed in the revised manuscript. An elevation similar to the present-day one during the early Oligocene, as inferred by some, may only be local in extent, because an extended plateau at this height would produce the monsoon-dominated climate pattern in Asia according to climate models, yet geological evidence clearly reveals a planetary climatic pattern in Asia during most of the Oligocene (Fig. 3c). These results, associated with the model outputs and geological records, likely support the notion of diachronous uplifts of the plateau.

Dr. Ramstein asked on if it is possible to check with the numerical stimulations our hypothesis that the changes in the hemispheric asymmetry of ice conditions during the Paleogene may account for the observed northwards shifts of climate zones from the Paleocene to the Oligocene. This is a suggestion of extremely importance, and would be an interesting collaborative project for the near future. Most reliable stimulations would need substantial amounts of new experiments using a model that couples ice-ocean-atmospheric dynamics while the AGCM we used (Zhang et al., 2007a, 2007b) could only provide some very preliminary insights. In this case, we have preferred to

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just raise the hypothesis but not to discuss it in detail in the current manuscript. However, some results derived from geological records and climate models are available (mostly relative to the Southern Hemisphere) and are supportive to the hypothesis. Consequently, we have added a summary of them in the revised manuscript. Also, the monsoon-like climate (but not a monsoon-dominated one) in the southern most part of China during the Eocene (Fig. 4) supports the hypothesis.

Dr. Ramstein suggested adding a discussion about the relative contribution of SW and SE monsoons to the Miocene moisture in the Loess Plateau with regards to the elevation of Tibetan Plateau, based on model outputs. This has been tentatively addressed in the revised version. A greater contribution from the southwest summer monsoon could be expected when the barrier effects of the Himalayas and Tibetan Plateau were smaller. Sensitivity experiments (Zhang et al., 2007a, 2007b) appear to be supportive to this phenomenon. We also express our thanks for his suggestion to measure the oxygen isotope composition to address this issue in the future, as is an ongoing study of our research team.

Reply to the comments from the anonymous reviewer (Referee #2)

Referee 2 requested to more clearly indicate the basal chronologies of the two sections (QA-I and Gaojiazhuang, ML-V). This has been emphasized in the revised version. QA-I is a section with a basal age of ~22 Ma. An onset of loess deposition is northern China by the early Miocene has also been confirmed by several other sections, including QA-II (21.6-7.4 Ma) (Guo et al., 2002), QA-III (21.4-11.4 Ma) (Hao and Guo, 2007) and Miziwan (18.5-11.6 Ma) (Liu et al., 2005).

We thank also the Referee #2 for the suggestion to consider the possible climate effects of the other mountain ranges in northern China, such as the Liupan and Qinling Mountains. The importance of such an approach has been indicated in the revised manuscript. A most reliable understanding of these effects would require a good regional climate model with higher resolution than for the AGCM we used (Zhang et al., 2007a, 2007b).

Interactive comment on Clim. Past Discuss., 4, 535, 2008.