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Biogeosciences
Discussions

Interactive comment on "Paleofires and the dynamics of carbon cycling in Chinese Loess Plateau over the last two glacial cycles" *by* X. Wang and Z. L. Ding

X. Wang and Z. L. Ding

xuking@mail.iggcas.ac.cn

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We wish to thank Referee #2 for detailed comments and constructive suggestions which will fairly improve the manuscript. Generally, we agree with the necessary uncertainty evaluation suggested by Referee #2.

Answers to specific comments are as followed:

1. Lack of direct measurement of d13C of soil organic matter below LGM section is another deficit of this paper, which requires unnecessary assumptions.

Reply: We recognize that lack of direct measurement of d13C of soil organic matter

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below LGM section will add additional uncertainty to the estimation. To this sense, we will use the newly measured d13C values of soil organic matter below LGM section for calculation.

2. Authors should show the uncertainty for each emission factor in Table 1. Ranges of estimation error for TGMER and BBF should be shown in Fig. 3 to 5. BCMSR also has its own uncertainty due to the errors in BC measurement, dry bulk density, and linear sedimentation rate (LSR).

Reply: In the revised manuscript, the uncertainty for each emission factor will be added in Table 1, and ranges of estimation error for TGMER and BBF will be shown in Fig. 3 to 5. The uncertainty regarding BCMSR will also be discussed in the revised manuscript.

3. There could be more uncertainties in authors' assumption other than emission factors. In equations (1) and (2), determination of f (relative abundance of C3 plants) is essential. The f is calculated from d13C of soil organic matter by the equation (3) assuming fixed d13C end-member values of C3 and C4 plants. These end-member values could be changed from time to time.

Reply: Plants use two principal biosynthetic pathways to fix carbon, the C3 and C4 cycles. C3 plants have δ13C values ranging from -22‰ to -34‰ with an average value of -27‰ and C4 plants from -10‰ to -14‰ with an average value of -13‰ (Farquhar et al., 1989). Many previous studies have employed the mean values of -27‰ and -13‰ as the d13C end-member values of C3 and C4 plants respectively when reconstructing C3/C4 abundances using d13C of soil organic matter (e.g., Gu et al., 2003; Liu et al., 2005; Wang et al., 2008). These two values are so far the most representative isotopic compositions for C3 and C4 plants since they were obtained using the statistics of a large number of plants in many different regions. Although the end-member values might change a little bit (not too much) from time to time, we cannot currently find a feasible way to disclose the changes in these values. This is still an open question to be resolved. In this case, we may provide a "best guess" for C3 and C4 abundance based on the available information to date.

4. Though the f is calculated from d13C, authors directly measure or cite the d13C data only for the interval from LGM to recent. Alternatively, authors chose to calculate the d13C by the equation (an empirical relationship between d13C and GSP) described in Fig. 2. The GSP is assumed to be proportional to MAP of each location. The proportion of GSP to MAP could be changed from time to time. MAP is calculated from MS using the equation (4). This means that, for the most of the stratigraphic intervals, the d13C is just a function of MS. Authors should calculate d13C for the interval since LGM using the same method and show the comparison between the calculated value and the measured data. This might give the uncertainty of the proportion of GSP to MAP.

Reply: It is true that the proportion of GSP to MAP could be changed from time to time. The fixed proportion of GSP to MAP used in this study may cause some uncertainty to the calculated d13C values. To eliminate this influence, we will adopt measured d13C values of soil organic matter below LGM section for calculation in the revised manuscript.

5. Error bars are also necessary for ANPP profile (Fig. 6). For calculation of ANPP, authors chose to use Thornthwaite Memorial Model to know net primary productivity with inputs of MAP and MAT. Authors used the equations (4) and (5) to calculate MAP and MAT from MS. However, their requirement of the equations (4) and (5) at the same time means that MAP and MAT have a fixed relationship as; MAP = (ln 11.18 - ln 8.8078 + 0.1908 MAT) / 0.0042 . Such a relationship could be changed from time to time. Authors also assume the fixed R/S ratio as 3.7 to calculated ANPP from the net primary productivity. However, R/S could be also changed from time to time depending on the climate (e.g. water availability). Again authors should show the relationship between calculated ANPP and measured (observed) one in the modern condition. This might give the uncertainty of the ANPP calculation.

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Reply: In modern monsoonal climate region like China, both precipitation and temperature increase in summer season and decrease in winter season. This means that MAP is proportional to MAT, just as the equation given by Referee #2. This relationship can be explained by the thermal gradient between ocean and continent, which is ultimately determined by temperature. For example, high temperature leads to large thermal gradient between ocean and continent, and therefore summer monsoon will be intensified and bring more rainfall inland. This fixed relationship will not change largely from time to time especially during the late Quaternary when the structure of modern ocean-continent distribution has been developed. But we agree with that the fixed Root to Shoot (R/S) ratio as 3.7 to calculate ANPP may incur some uncertainty. The R/S ratio for a certain pant is known to be affected by nutrient supply, carbon supply and water stress (Johnson, 1985; Sievanen et al., 1988; Hilbert, 1990; Dewar, 1993; Reynolds and Pacala, 1993; Cannell and Dewar, 1994). Changes in R/S ratio under elevated CO2 have varied among studies, ranging from increases to decreases, or no effects (Hunt et al., 1991; Rogers et al., 1994). The basis for this variation is unclear, but may be related to differences in water or nutrient supply, as well as to species differences. Due to the more complicated effect of CO2 on R/S ratio, we don't consider this factor in this study. By contrast, the effects of temperature and precipitation on R/S ratio are relatively clear. For example, a recent study has revealed that R/S ratios decreased significantly as annual precipitation and mean annual temperature increased for shrubland and grassland (Mokany et al., 2006). To reduce the uncertainty from fixed R/S ratio, we could use different R/S ratios according to the changes in precipitation and temperature between the glacial and interglacial periods in the revised manuscript. Meanwhile, error bars will also be given for ANPP profile.

6. It is very difficult to judge if the description here is reasonable without an evaluation of uncertainties for their calculations. But, repeatedly, authors should be careful because most of their estimation tends to be affected by (or mealy functions of) linear sedimentation rate and MS significantly. Assumptions (equations (4) and (5)) might be too strong.

Reply: In the revised manuscript, we will add in an evaluation of uncertainties for our calculations to aid the readers understanding this study. It is just a surface phenomenon that most of our estimation tends to be affected by (or mealy functions of) linear sedimentation rate and MS significantly. Actually, the first order controlling factor is monsoonal climate. Wet-dry cycle of monsoonal climate determines fire occurrences and thus BC production, trace gases emission and burnt biomass in Chinese Loess Plateau (Wang et al., 2005). Meanwhile, the linear sedimentation rate is also determined by wet-dry cycle of monsoonal climate, i.e. the sedimentation rate of loess was high during the glacial periods with cold and dry climate prevailed (Ding et al., 2001). By contrast, magnetic susceptibilities (MS) of loess and paleosol are governed by both temperature and precipitation. For examples, MS was low during cold/dry glacial periods whereas it was high during warm/wet interglacial periods (An et al., 1991; Sun and Liu, 2000). Therefore, climate links all these proxies together. In this case, our estimations for trace gases emission and biomass burnt by fires seem to be related to sedimentation rate and MS. Reconstructions of paleorainfall and paleotemperature are the most important and still open questions in paleoclimatic studies. Some previous studies have reconstructed rainfall and/or temperature based on some paleo-proxy indicators such as magnetic susceptibility (Liu et al., 1995; Maher and Thompson, 1995; Porter et al., 2001), pollen assemblages (Webb et al., 1993; Bonnefille and Chalié, 2000; Guiot and Couteaux, 2006), phytolith assemblages (Prebble et al., 2002; Lu et al., 2006). Since both pollen and phytolith assemblages are identified under microscope and the uncertainties for species percentages determined usually depend on individual professional skills, these two approaches tend to incorporate additional arbitrary errors. By contrast, the magnetic susceptibility is measured directly using instruments, which possess high precision and reproducibility. Meanwhile, the linkages of MAP and MAT to MS (as shown by equations (4) and (5)) were obtained by modern observation (Porter et al., 2001), reflecting the most representative relationships in the region. This is by far the most accessible and reliable data we can use for our calculation.

7. It is also difficult to judge if the description here is reasonable without the examination of their methods. However, their discussion itself seems to be biased by their assumption in their method. In Page 4473 – Line 1, authors estimate the anthropogenic fire emission during late Holocene, which is comparable to the emission difference between glacial and interglacial periods. However, because authors calibrated their algorithms that relates carbon emission to climate using modern condition under anthropogenic perturbation, it might not be appropriate to use such a relationship for past carbon emission reconstruction.

Reply: The algorithms used for the TGMER and BBF estimation in this study are mainly based on fire carbon emission factor which was used to translate the fire carbon loss to trace gas and aerosol emissions. The fire emission factors we used in this study were obtained through field fire observation and laboratory burning studies, and received a critical evaluation (Andreae and Merlet, 2001). They may represent the most acceptable and reliable data for fire emission modeling studies to date. Fire carbon emission factor depends primarily on the composition of the fuel (e.g., C3/C4 abundance) and combustion conditions (Lobert and Warnatz, 1993; Andreae and Merlet, 2001). Both of them are ultimately governed by climate condition (e.g., humidity and wind speed) (e.g., Korontzki et al., 2003). Although human activities widely exist in modern time, anthropogenic perturbation does not influence vegetation specific fire emission factor. The only thing that human perturbation influenced is fire occurrence (i.e., fire frequency and/or intensity), which would be reflected in our BCMSR records. In this sense, we consider that the observed relationship of fire carbon emission with modern climate although under anthropogenic perturbation could be used for past carbon emission reconstruction.

8. In Page 4474 - Line 13, author attributed over 100% BBF/ANPP to below-ground biomass burning. However, it might be explained by the change in root / shoot ratio.

Reply: The ratios of biomass burnt by fire to above-ground net primary productivity (BBF/ANPP) over 100% usually occurred during the glacial periods when climate was cold and dry. Many previous studies have shown that fires in Chinese Loess Plateau were more frequent during the glacial periods than during the interglacial periods (Wang et al., 2005). Therefore, the frequently occurred fires would consume more-than-usual biomass. Pollen studies in Chinese Loess Plateau have indicated grassland expansion during the glacial periods (Sun et al., 1997; Jiang and Ding, 2005; Tang et al., 2007; Sun et al., 2010). More grassy fuels in vegetation stand for relatively less ANPP available for burning. In this case, the intensified fires during the glacial periods may not only consume nearly total of the above-ground biomass but also burn some of the below-ground biomass. This is supported by some modern fire studies in grassland (Barbosa and Fearnside, 2005; Song et al., 2009). In this study, we adopted 3.7 as an R/S ratio of vegetation in Chinese Loess Plateau (CLP). This value is close to a newly calculated mean value of 4.2 for the R/S ratio of temperate grassland (Mokany et al., 2006). Therefore, we consider it may be a reasonable value for the R/S ratio of modern grassland in CLP. Since R/S ratios decreased significantly as annual precipitation and mean annual temperature increased for shrubland and grassland (Mokany et al., 2006), the root/shoot ratio of grass vegetation in CLP would increase due to cold and dry climate during the glacial periods. That means the actual R/S ratio during these periods may be higher than the currently adopted value of 3.7. If the over 100% BBF/ANPP could be explained by the change in R/S ratio, then the actual R/S ratios during the glacial periods are expected to be lower than the currently adopted value of 3.7. By this way, there would be more ANPP than what we currently reconstructed to account for high BBF assuming no below-ground biomass was burnt. However, the expected R/S ratio (<3.7) is contradicted to what it should be as we discussed above. So we cannot agree with the alternative explanation to the over 100% BBF/ANPP as suggested by Referee #2.

9. Fig. 1 No explanation for broken lines.

Reply: The broken lines in Fig. 1 indicate the rainfall contour lines. This will be added in the revised manuscript.

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