Response:

General comments: This study contributes to science with an analysis of impacts of aerosols and clouds on grasslands net ecosystem exchange (NEE) of a semi-arid grassland in the Loess Plateau in north west China. The study uses a unique data set of NEE, meteorology, AOD's and solar and solar diffuse radiation measurements. It adds to the limited knowledge on the response of grasslands NEE, photosynthesis and ecosystem respiration to clouds and aerosols.

This is a well written article, with a well described methodology and results. The paper includes a good analysis of carbon fluxes under various cloudy conditions. However, the analysis on impacts of aerosols on carbon fluxes misses on the temperature effects. It seems that the diffuse radiation effect (which is low) on photosynthesis is counteracted by the temperature effect on ecosystem respiration, but this is not really shown and discussed.

Response: We appreciate reviewer's suggestion and have taken it into account in our revised manuscript. In the revised paper, we have added Fig.12 to show the combined influence of temperature and diffuse radiation (via aerosols) on carbon fluxes. 'Under a clear sky condition the air temperature is higher than that under other sky conditions (Fig. 8). From Fig. 9, we see the CO_2 uptake reduces with the increased air temperature. Thus, a further analysis is required to see if the effect of aerosol loading on the carbon uptake is also significant under same temperature. Fig. 12 shows that the higher AOD (AOD>0.5) still results in a more pronounced decrease in CO_2 uptake (decreased photosynthesis) with increasing air temperature, as compared to situations with lower aerosol loading (AOD<0.3). However, the weakening extent of carbon uptake with AOD is decreased compared with that in Fig. 11. Although this seems to indicate the existence of a negative effect of AOD on carbon uptake, it may not be a major factor in regulating the ecosystem carbon exchange.'

Furthermore, from Fig.11 we can see the decreased effect of AOD on CO_2 uptake is the combined result of the decreased effect of AOD (due to increased diffuse fraction of PAR) on photosynthesis and the increased effect of AOD on respiration. At the same temperature, the decreased effect of AOD on NEE and photosynthesis still exists but reduced (Fig.12). This shows that the increased effect of temperature on respiration and the decreased effect of diffuse PAR on photosynthesis combine to produce a net decrease in NEE. It seems to us that, for our site, there is a tendency of decreasing carbon uptake with increasing AOD.

Specific comments:

Question 1: On the same topic, Figure 11 could be modified to show, how in clear sky days (under aerosol loaded conditions) NEE, photosynthesis and ecosystem respiration vary with AOD, diffuse fraction, and temperature. Figure 11 has i) a considerable amount of scatter in the data, ii) very few points at low CI which seem to be driving the slope of those regression lines, and for this reason, those lines should not be there, especially the one with AOD higher than 0.5.

Response: In response to the above comments, we have added Fig.12 to show how in clear sky days (under aerosol loaded conditions) NEE, photosynthesis and ecosystem respiration vary with AOD and temperature. The results show that the weakening extent of carbon uptake with AOD for the same temperature is decreased compared with that in Fig. 11. Although this seems to indicate the existence of a negative effect of AOD on carbon uptake, it may not be a major factor in regulating the ecosystem carbon exchange

Although Fig. 11 shows a considerable amount of scatter in the data, all the curve fittings pass the significance test, except for the ecosystem respiration rate with CI when AOD>0.5 (only 28 points). With only a few data points for the clear sky conditions, we make only a limited qualitative statement regarding the effect of AOD on carbon uptake under these conditions. Having said that, however, the results do appear to show a tendency of decreasing carbon uptake with increasing AOD.

Following the review comments, we have redrawn Fig. 11 in the revised paper. Considering only few points fall at low CI, we have recalculated the curve fitting to include only those points whose CI are larger than 0.65, to show the effect of aerosol loading on carbon exchange with the increased diffuse fraction more clearly.

Question 2: There seem to be two messages: 1) The diffuse radiation effect due to aerosols on photosynthetic C uptake of these grasslands, (how much is this?) and 2) the counteracting effect of ecosystem respiration due to temperature (how much is it?).

Response: Consistent with our response comments so far, we see in the revised Fig. 11 the carbon uptake decreases (the photosynthesis decreased and respiration increased) with the increased AOD (due to increased diffuse fraction) for the same CI. For AOD<0.3 and AOD>0.5, the increased NEE (increased carbon uptake), decreased photosynthesis and increased respiration are about 2.7, 2.6 and 0.02 μmol m^{-2} s^{-1}. This shows that the effect of aerosols on carbon uptake is mainly through photosynthesis rather than respiration. In addition, according to Fig. 9 and Fig. 12, the temperature effect on ecosystem respiration is relatively small, and for the same temperature the respiration is relatively unchanged with the increased AOD (Fig.12c). The carbon uptake still shows the decreased tendency with the increased AOD at same temperature.

Question 3: The authors mention through the text, that diffuse radiation photosynthetic enhancement is not as large as in croplands and forests, due to the lower light saturation points of forest and croplands. The respective light saturated values of forest and croplands should be stated in the text to put more context into such statements. The authors could also include values of light saturation points from other or similar grassland ecosystems.

Response: Thank you for the suggestion. But first we like to point out that it is the “lower light saturation points of grassland” and not of “forest and croplands.” In section 4.2, Fig.3, a cubic regression curve fitted to the data delineates a relationship in which NEE reaches a minimum (maximum net uptake by the vegetation) with a CI value of about 0.37 (corresponding to the solar radiation of about 434.8 W m^{-2}) for the short grass over semi-arid regions, and is in the low end of the range 0.4-0.7 observed for some forest systems (Gu et al., 1999; Oliphant et al., 2002). In addition, we have included the comparison of the relationship between the carbon uptake and temperature for grassland at the SACOL site (Fig. 9) and cropland (Norman et al., 1991) in the revised paper. At the SACOL site, the temperature with maximum carbon uptake is less than 20℃, but for the corn and soybean, they are around or larger than 30℃。These relationships also confirm the fact that the vegetation canopy at SACOL reaches the light saturation point at a lower temperature, resulting in a carbon uptake reduction with higher temperatures.

Question 4: On the temperature effect on photosynthesis, some of the following issues could be included in the discussion, if there was information on it. Are there any other studies showing the same response to temperature? Is the temperature response of photosynthesis found in this study also found in other or similar grasslands under similar environmental conditions? Are there any gas exchange measurements confirming the observed photosynthetic response to temperature?

Response: This paper is a preliminary study of clouds and aerosol loading effects on the carbon uptake by a grass ecosystem located at the semi-arid Loess Plateau region. These loading effects are examined under different conditions of temperature which by itself is an important factor influencing the ecosystem carbon exchange. Previous studies have focused mainly on the forest canopy, with larger leaf area index (LAI) and higher photosynthetic capacity. Few have investigated the case over semi-arid regions with short-stature canopies. Niyogi et al. (2004) did analyze the effects of aerosol loading on NEE over different ecosystem landscapes, and the results for the grasslands also show a negative response to the aerosols, which is consistent with our results. However, they fell short of making a further detailed analysis, and didn't show the relationship between temperature and NEE.

It is a pity that there are at present no other gas exchange measurements that can be used to confirm the results of this paper at the SACOL site. In June of this year however, a PAR *LITE* has been installed to measure the PAR of vegetation. Thereafter there will be other instruments to be purchased and installed successively at the SACOL site. It will provide more opportunity for us to study the carbon exchange over this semi-arid Loess Plateau of Northwest China.

Question 5: Cloudiness data: It would be very good to see the relationship of global radiation and cloudiness derived for this study with the method from Long et al. This could be placed in the main text or in an appendix.

Response: We appreciate reviewer’s suggestion and have incorporated it in our revised manuscript. In the revised paper we added an appendix to briefly describe the estimation of cloudiness using the measured 1-min measurements of surface downward total and diffuse shortwave irradiance at the SACOL site. Because of the complexity of the calculation involved, we only briefly give the limited condition for total solar radiation and diffuse radiation under various sky conditions. The more detailed explanation about the determination of limit value can be found in Long et al. (2000, 2006) and Wang (2009).

Long, C. N. and Ackerman, T. P.: Identification of clear skies from broadband pyranometer measurements and calculation of downwelling shortwave cloud effects, J. Geophys. Res., 105(D12), 15609– 15626, 2000.

Long C. N., Ackerman, T. P., Gaustad, K. L., and Cole, J. N. S.: Estimation of fractional sky cover from broadband shortwave radiometer measurements, J. Geophys. Res., 111, D11204, doi:10.1029/2005JD006475, 2006.

Wang, T. H.: Retrieving optical and microphysical properties of mixed-phase and dusty cloud over Northwestern China from MFRSR, Ph. D. dissertation, Lanzhou Univ., Lanzhou, China, 90-92, 2009 (in Chinese).

Technical comments:

1. Page 2 (abstract) Line 11, ‘light saturation levels in ‘the’ canopy are lower, with a value of about ‘. Lower than which values?. Page 2 (abstract), Line 12, define CI (first time that it is mentioned). Page 2, Line 14, clearness index is mentioned, please define.

Response: We have changed ‘lower’ to ‘low’. Perhaps we have also caused some misunderstanding. This value we give is the average light saturation levels of vegetation at the SACOL site in July and August of 2010. In addition, we add the definition of CI in the abstract. We have also included a definition of the “clearness index.”

2. Page 2, Lines 14-15. ‘Under other sky conditions the CO2 uptake decreases with the cloudiness but the light use efficiency is enhanced, due to increase the fraction of diffuse PAR’. Rephrase, ‘Under other sky conditions, CO2 uptake decreases with cloudiness, but light use efficiency is enhanced, due to increased diffuse fraction of PAR’.

Response: Thanks for the suggestion. We have rephrased the sentence accordingly.

3. Page 3, Lines 11-12 ‘Under cloudy and aerosol conditions’, under aerosol conditions reads very strange, it could be reworded to read better.

Response: We have changed ‘under cloudy and aerosol conditions’ to ‘Under cloudy conditions and with aerosol loading’. We think this makes the sentence more clearly.

4. Page 3, Line 14,-15 for the North America ’n’ forests.

Response: We have changed ‘America’ to ‘American’

5. Page 5, lines 1-2, are these grasses C3 or C4?.

Response: We consulted the related literature and found that the vegetation at the SACOL site belongs to C3. We have included this in the revised paper.

6. Page 9, equation 5a, please define ïA˛ (Greek letter m).

Response: Thank you for pointing this out. We add the definition of η in Eq.7a. u =4.55 μmol J^{-1}, is an average of conversion quantum coefficient given by Zhou et al. (1996).

7. Page 11, lines 18-24, Very long sentence, it could be cut into two sentences. Hard to follow what the authors mean in lines 22-24.

Response: We have changed the sentence and cut it into two sentences. We think it can make the sentence more readable.

8. Page 13, end of Line 21, replace diffusion with diffuse.

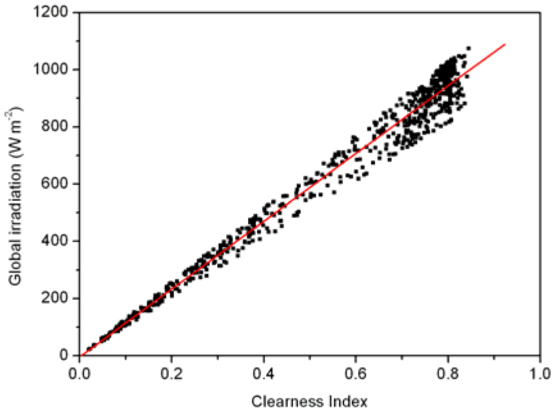
Response: We have replaced 'diffusion' with 'diffuse'.

9. Page 16, line 26. There are at least 9 points with diffuse fraction higher than 0.6.

Response: Thank you for pointing out the error in the manuscript. Indeed, most diffuse fraction is less than 0.6, but there are several points with diffuse fraction higher than 0.6. Thus, we changed the sentence to 'rarely does D_f become greater than around 0.6, allowing total solar radiation to surpass the grassland light saturation point quickly'.

10. Page 17, lines 1 and 2. 'under a high aerosol loading condition, CI can still be large, corresponding to a high solar radiation (about 1000 W m-2)'. Where is this shown?

Response: From Fig. 11 we can see that under a high aerosol loading condition (AOD>0.5), clearness index can still reach around 0.8. According to the relationship between CI and total solar radiation (not shown in the manuscript), the solar radiation will be about 900 W m^{-2}. We have revised the value in the manuscript accordingly.



The relationship between total radiation and clearness index.