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Interactive comment on "Role of net radiation on energy balance closure in heterogeneous grasslands" *by* C. Shao et al.

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General remarks This manuscript investigates the influence of net radiation measurements on the energy balance closure. The study is based on data from three grassland eddy covariance sites where in one experiment the effect of the natural spatial variability was investigated and in another experiment inhomogeneity of the vegetation height was deliberately created by different clipping regimes of the grass within the footprint area. In addition the effect of dome aging of the Q7.1 net radiometers was also analyzed. Other net-radiometers used in this study were of type CNR-1 by Kipp and Zonen.

Weaknesses of this study are - the use of Q7.1 instruments, which are known to be low quality sensors, and not suited for high-precision measurements and energy-balance

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closed studies, but apparently they are still in use at some long-term flux measurement sites, therefore there is some justification for this analysis

- the influence of radiation sensor uncertainty on energy balance closure has already been investigated in a much more comprehensive study by Kohsiek et al., where a wide selection of instruments was deployed and a number of high-quality radiation sensors (secondary-standard) were available - based on the experience from previous studies on energy balance closure and from fundamental considerations, it is clear from the beginning that the uncertainty of net radiation measurements, may it be due to instrumental error or due to spatial variability, is of more or less random nature and will therefore not be able to explain the systematic bias that we are looking for and as it manifests itself in the commonly found lack of energy balance closure (convective heat fluxes generally 10-30% lower than the available energy at the surface).

Kohsiek et al. (2007) compared the differences from many kinds of radiometers in their cotton fields and draw a conclusion that spatial variation is also a reason for the Rn measurement differences. But they did not quantify these differences. We quantified the differences in the grasslands and found the difference among the Q7.1 sites is only 20 W m-2, which is much smaller than the reported imbalance of about 100 W m-2 in the literature and from our study, even added all the system errors and the spatial variability. We do not deny these differences perhaps derived both from the instruments and the spatial variation. We designed this study try to illustrate the reasons and magnitudes of energy unclosure from the two commonly used net radiometers- Q7.1 and CNR1 in the field. Only after we considered these uncertainties from Rn, we can further compare the EBCs between eddy covariance sites and clarify the effects of unclosure on the EC measurements. Although the loss energy derived also from the turbulence energy, the contributions from the available energy could not be neglected. We did noticed some former studies just compared EBCs among site while they did not consider the large differences from the Rn measurements and even constructed relationships between the CO_2 fluxes or Bowen ratios with their EBCs.

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- Incomplete post-processing of the eddy-covariance data

We thoroughly revised this part with "2.7 Eddy-covariance data processing and gap filling The July to September raw 10hz TS data from the eddy covariance measurements were processed off-line using the EC_Processor software package (http://research.eeescience.utoledo.edu/ lees/ECP/ECP.html) (Noormets et al, 2007; 2010; 2008) for sites I, II and III, respectively, which were corrected by the double rotation method. The turbulent fluxes were adjusted for fluctuations in air density using the Webb-Pearman-Leuning expression (Webb, 1980). A series of data quality controls were used in the EC_Processor and before the gapfilling, for example, data quality was judged by atmospheric stability. Obvious outliers were removed, such as anomalous or spurious data that were caused by sensor malfunction, sensor maintenance, rainfall events, IRGA calibration, power failure, etc. The friction velocity u* (Goulden et al, 1996; Moncrieff et al, 1996) <0.15 m s-1 were used in this study (Zhang et al, 2007). After these quality tests the remaining data were classified as 'good data' to submit to gap-filling procedure. Consequently, 29, 21 and 28% of the July-September growing season data obtained from our EC systems of sites I, II and III, respectively, were discarded in experiment 1. These larger data gaps were filled using empirical relationships (look-up tables) following the methods of Falge et al. (2001) for gapfilling sensible and latent heat fluxes. Linear interpolation was used to fill the gaps that were less than 2 hours by calculating an average of the values immediately before and after the data gaps. For each site, one look-up table, which sorted by photosynthetic photon flux density (PPFD) and vapor pressure deficit (VPD), was created from July 1 to September 30. After gap filling the data, the corresponding non-raining day's forty-eight half-hourly values per day were extracted and analyzed with the net radiation and soil heat flux data."

Strengths/interesting aspects of this study are - investigation of the impact of spatial variability of net radiation, which may lead to a mis-match in footprints/source areas of radiation measurements and eddy-covariance flux-measurements

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Therefore this reviewer suggests major revisions focusing on the interesting aspect, i.e. the spatial variability. This means the overall research question should also be shifted. However, if the authors agree to do so, more and deeper analysis is required. It is necessary to compute flux-footprints of the eddy-covariance measurements and compare them with the source areas of the net radiometers. Particularly, the experiment with different clipping regimes could be yield interesting results. In order to improve the comparison with the eddy-covariance measurements more effort needs to be directed into a comprehensive data-post-processing of these flux measurements including all necessary corrections and quality checks.

Thanks for your recommendations. The unclosure of energy balance is due to underestimation of the turbulent flux and/or overestimation of the available energy. The Rn is the largest flux term in the energy balance of a terrestrial ecosystem. Fluctuation of a small percent of Rn would significantly affect the EBC. Our primary goal of this manuscript is to detect the role of net radiation measurement uncertainties and its action on the energy balance closure. Specifically, (1) What is the magnitude of the spatial variability in Rn at the three EC measurements grassland sites? (2) What are the potential causes of Rn variation within and between eddy covariance measurement grassland sites? (3) What are the contributions of Rn to EBC at these sites due to its spatial variation caused by heterogeneous vegetation? To answer these questions, we considered our conditions and designed four field experiments in a typical grassland type of Inner Mongolia and applied a mobile energy system, which consists of nine net radiometers and other meteorological sensors with three eddy flux towers to record spatially independent Rn and associated surface properties (i.e., vegetation).

We double checked and rewrote the data process part with more details as mentioned above. We also attached our lookup table data for gapfilling the turbulence fluxes, and the data of regressing the available energy against the sum of turbulent fluxes and the good data criterion of site I in a separated excel file. We like further discuss on these data.

Minor comments The use of the English language is gerenally okay but sometimes the wording is not as precise as it should be, e.g. the word "energy" and the word "flux" are sometimes interchanged. L60: available energy instead of available flux

We changed accordingly and used the energy instead of flux throughout the ms under the same conditions.

L66/67: Better: Yet no universally valid theories for

Changes have been made accordingly in L63/64.

L96: here it is not sufficient to speak of our sites when they are not introduced yet, be more precise and neutral, e.g. measurements for this study were conducted at three test sites in Inner Mongolia.

Changes have been made accordingly in L91. We added the new sentence with 'Measurements for this study were conducted at three test sites in Inner Mongolia.' in the text.

L99: mobile energy flux measurement system instead of mobile energy system

Changes have been made accordingly in L97.

L123: Better: Spatial variability of Rn with the EC flux footprint instead of within the EC flux towers

Changes have been made accordingly in L124.

In general, it would be helpful to show schematic maps of the set-ups of the experiments 1 and 2

Thanks for your suggestions. This is another good choice, but considering the length of the ms, we selected to illustrate the designs with words in L130-140 and L155-160.

Fig appendant1. Sketch map of mobile energy balance (EB) system

Fig appendant2. Sketch map of mowing treatments. The mobile energy balance (EB)

system layout is also shown.

L157: dominant instead of dominate

Changes have been made accordingly in L161.

L205: The double rotation method and the Webb-Pearman-Leuning expression are two completely different processing steps. More details about the post-processing is required, e.g. correction of spectral losses etc.

Thanks for your correction. We rewrote the data process part with more details as mentioned above.

About the low and/or high frequencies spectral losses is another reason from turbulence measurements caused the imbalance of energy balances. The spectral losses at low frequencies are not so much instrument related as they are related to the length of the sampling period and the nature of the low frequency atmospheric motions present during a sampling period. Because so little is known about the nature of these low frequency atmospheric motions (1-4hours) it is difficult to make specific recommendations for reducing this undersampling error. Further research is needed into the low frequency components of eddy covariance fluxes and in the nature of the differences in the frequency-weighted cospectral peaks between different sites. From the literatures, flux loss was typically 5 to 10% for sensible and latent heat flux (Moore, 1986). In our three sites, the average noon H+LE was near 300-400 W m-2, so the spectral loss perhaps reached to 15-40 W m-2, which is also important in EBC. We added this in the discuss part of the manuscript in L341-345.

L231: turbulent flux instruments instead of turbulent energy instruments

Changes have been made accordingly in L240.

L232: periods instead of period

Changes have been made accordingly in L241.

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L304: could be reduced instead of could be neglected

Changes have been made accordingly in L313.

L312: too small instead of smaller

Changes have been made accordingly in L321.

L318: Please differentiate between random measurement errors and the systematic underestimation of the convective energy fluxes

We double checked and recalculated the data and added the stand deviations of the Rn, G, and the systematic underestimation of the convective energy fluxes across the three sites in the peak time of the measurement periods as following: "The uncertainty in Rn could contribute to a systematic error of about 20 (21 ± 3 in midday across the three sites) W m-2, or 5% of Rn which is in consistent with the report by Twine et al. (2000) of 6% of midday and mid-season Rn at a grass site in Oklahoma. The uncertainty in soil heat flux could contribute another 50 (53 ± 11) W m-2 of error to the available energy (Shao et al, 2008). Altogether, the inclusion of the uncertainty in available energy accounted for about 65% of the 110 (111 ± 10) W m-2 shortfall in the lack of closure."

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Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/8/C952/2011/bgd-8-C952-2011-supplement.zip

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