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Biogeosciences Discussions



# *Interactive comment on* "Heat storage in forest biomass significantly improves energy balance closure particularly during stable conditions" *by* A. Lindroth et al.

**Anonymous Referee #2**

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The study of A. Lindroth et al. (2009) considers the surface energy balance closure over tall forest vegetation and focuses particularly on the role of the energy storage below the eddy-covariance (EC) measurement height. The authors utilize old but presumably unpublished dataset of biomass temperatures measured in several tree compartments to evaluate the biomass heat storage (Sbio) in detail. Although the studied site in Norunda, Sweden, is a mixed boreal coniferous forest, the results can be considered to represent the tall vegetation in general.

I consider the paper technically solid. The estimation method for biomass surface temperature changes and Sbio are well documented and necessary details are given. All

the analyses and most of the measurements (see specific comments) are adequately represented and they can be considered reliable. From technical viewpoint the paper merits publication after some polishing.

The authors answer in detail to the first aim of the paper: They quantify the energy balance components in detail and show that including Sbio significantly improves the average energy balance closure (EBC). This is expected in light of earlier studies (e.g. Oliphant, 2004) and further shows the importance of "thermal inertia" of the surface for temporal variability in surface energy fluxes. I, however, consider the stability dependency of the energy balance residual (Qres) found in the study the most interesting result and it needs to be discussed in more detail to answer the second aim.

In nighttime the sensible heat flux decreases significantly in strongly stable stratification due to the decaying turbulence. Consequently, the role of the energy storage (including the ground heat flux as in this study) gets more pronounced as shown in Fig 9. In these conditions including the measured storage term closes the energy balance almost perfectly and it could be argued that the advection and nocturnal drainage flows do not exists at the site in these conditions. It can also be considered as a validation of the storage measurements. However, in the slightly stable conditions, when the turbulent fluxes still are important component of the nocturnal energy balance, the EBC is less good – and the measured EC fluxes + Qres actually exceeds the net radiation. This could imply that the EC fluxes are still underestimated in stable conditions, in contrary to the author's conclusions. If you assume that the accuracy of the storage term is independent of stability, then the behavior in Fig. 9 can be explained e.g. by insufficient spectral corrections etc. – the absolute influence of multiplicative corrections decreases when the "raw" flux approaches zero. Please discuss the effect of stability in more detail and contrast the results against earlier studies such as Barr et al. (2006) who found reversed stability dependence during nighttime. Also, showing net radiation as a function of Ri would be interesting.

The daytime stability dependency of Qres deserves also deeper discussion, for in-



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stance in light of recent review-study of Foken (2008). The reasons for poorer EBC in very unstable conditions should be considered, even speculatively. These could include large eddies (e.g. Kanda et al., 2004), secondary circulations forming in strongly convective conditions (which could be coupled with weak vertical wind shear and low u*) and entrainment of dry air (e.g. Davis et al. 1997).

The shallow and short discussion is clearly the weakest point of the paper and needs a revision. This will also significantly increase the value of the paper.

Finally, the paper should be edited by a native English speaker to improve the clarity and flow of the text.

Specific comments

Short title: The title should be generalized - the study is not limited on stable conditions, i.e. “Heat storage in forest biomass improves energy balance closure”

p. 8534 l. 8-9. Reformulate the sentence. Are there any studies to cite?

p. 8535 l. 1-3. Did the findings of Moderow et al. (2009) motivate the present study of why the old dataset is now picked up and analyzed?

p. 8535 l. 5-14. Use “eddy-covariance” instead of “–correlation”

p. 8536 l. 7-26. Were the EC gas sampling line heated? How about the profile setup – were the sampling lines heated and equal length etc. Please provide some more details although the references are given.

p. 8537 l. 1-2. What you can say about the source area of the net radiometer? How does it relate to the turbulent flux footprint during different stabilities? Can horizontal variability of the source area characteristics explain any of the stability dependency of daytime EC (Fig. 10 & 11). Are there any differences in EBC if the dataset is stratified into wind sectors?

p. 8538 l. 15 What is meant by “topographic area”? Please define.



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p. 8540 l. 3-12. Table 3 is mentioned before Table 2 is introduced. Please change accordingly.

p. 8540 l. 16-19. I would prefer mathematical symbols instead of some arbitrary numbers (where do they come from – certainly from none of the tables?) when discussing the storage scaling.

p. 8541 l. 6-10. I assume the eq. 9 is not developed by the authors? Please provide the reference.

p. 8541 l.17 What is meant “at the same height”? Same to what – or do you mean that at each height where the biomass temperatures were measured?

p.8541 l. 25-26 What meand that you calculate the frequencies by Fourier analysis? If you operate in wave number (k) space (alternatively in frequency space) you get out the “amplitude” of the variability associated with each k, a(k), and that should be what you are interested.

p. 8542 eq. 14: Splate is a bad acronym; you mean the soil heat storage above the heat flux plates, not in the plate itself.

p. 8543 l. 15 The definition of latent heat storage is not correct. dq/dt below the measurement height may be caused by temporal changes in turbulent transport, sources – and also by phase shifts.

p. 8544 l.13-16 The authors should note that they intentionally use gradient Richardson number which is independent of EC flux measurements. Use a different acronym for potential temperature instead of T.

p.8546 l. 23 Typo: “peek” → peak

p. 8547 l. 24-25 Reformulate the sentence; storage flux and small increase of R2 are not added. . .

Figures



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Fig 1. Caption mentions average temperature – give the averaging time

Fig 3. Caption: add “biomass storage flux” instead of “storage”. Change the line colors / symbols to be more distinct; in present version the color scale is too narrow.

Fig 4. Same here, change line colors / symbols.

Fig 5. Maybe you could add a normalized / down-scaled net radiation curve here to visualize the time lags of the storage terms.

Fig. 6. Line colors / symbols should be more distinct. Maybe thicker line for Rn – the reference flux here. Were the shown nights extremely stable because H stays close the zero, particularly in 14/7.

Fig. 9-11. How you define nighttime and daytime?

Fig 11. I assume the imbalance term is with storage? This information is missing from the caption.

References

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Foken T. (2008), The Energy Balance Closure Problem: An Overview. Ecol. Appl., 18(6),1351-1367.

Kanda M., Inagaki M., Letzel O., Raasch S. and Watanebe T. (2004), LES study of the energy imbalance problem with eddy-covariance fluxes. Boundary-Layer Meteorol.,



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Interactive comment on Biogeosciences Discuss., 6, 8531, 2009.