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Interactive comment on "Seasonal and inter annual variability of energy exchange above a boreal Scots pine forest" *by* S. Launiainen

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The study synthesis long-term eddy-covariance data collected at a boreal pine forest and focuses on seasonal and inter-annual variability and their causes. It aims to describe the means and variability of energy exchange at a single boreal forest site, link the seasonal changes of energy partitioning to the annual cycle of the vegetation and discuss the energy fluxes in light of physiological knowledge. I want to express my gratitude to Dr. Werner Eugster and the anonymous referee for their valuable comments, which have significantly improved the clarity of the manuscript. Below I answer to the comments and describe the main changes done to the final version of the MS.

Response to the Interactive Referee Comment by Dr. Werner Eugster (7th Oct, 2010)

Figures

The reviewer comments regarding figures were considered and font size was increased from 10 pt to 12 pt in all figures. Fig. 3: Alternate y-axis labels were removed since conversion from W m-2 to MJ m-2d-1 is trivial. Fig. 4: Missing y-axis labels were corrected Fig. 5: The ensemble diurnal cycles (Fig. 4 & 5) are calculated on hourly basis; i.e. from midnight to 01:00 AM etc. and the corresponding value is assigned to 00:30 AM. I see this best way to present the ensemble values. Fig. 6: For clarity, a horizontal line α=1 was added to lower panel as suggested and described in caption. The medians for Nov-Feb period were not shown because the variability is extremely large and hence "typical" conditions (for which a median would be a relevant measure) do not really exist. Moreover, as discussed in the following (response to C5), the Priestley-Taylor –concept should be used only in convective conditions (McNaughton and Spriggs, 1989) and is defined for cases when advective fluxes are negligible and no inversion exists. Fig. 8: Labels were corrected and scientific notation (e.g. mm s-1) is now used throughout the MS. Fig 10: The figure was revised and panel size increased.

Tables

Blank cells indicate that the particular variable was not measured during the given year/period. Previously N/A and blank cells were both assigned for this purpose.

Text

C1: Reference to Table 2 was removed (p. 6455 l. 9).

C2: I agree. Word"minimum" changed to "growing season minimum".

C3: Sentence removed since it was not needed.

C4: There was a clear mistake in the text (p 6456-16 l. 16). The correct term, as noted by Dr. Eugster, is "potential evaporation", not "equilibrium evaporation (eq. 6)", which refers to radiation-driven evaporation rate from an extensive saturated surface in case when the atmosphere and the surface are in equilibrium (i.e. no vapor pressure gradient). Thanks for finding out this mistake, made during proof-editing phase!

C5 (p. 6456 l. 17-19): Priestley and Taylor (1972) model (or concept, more precisely) is to my understanding developed for conditions when advection as a heat source can be neglected compared to the net radiation excess at the surface. In addition, Priestley and Taylor (1972) restrict the plausible values of α assuming H$\geq$0 (no inversion) and allowing any condensation (their eq. 7b,c). McNaughton and Spriggs (1989) suggest P-T concept to be used only in convective conditions. In wintertime sensible heat flux is often directed towards the cooler surface and may represent additional energy source beyond the net radiation, conditions against the assumptions of P-T concept. The Priestley and Taylor (1972) α, "index of aridity" in their own words, has evolved to a kind of standard to compare evapotranspiration between different ecosystems and therefore I use it also in this study. The above discussion answers also to the related question by the anonymous referee. The discussion concerning the winter LE was shortened in the final version of the MS.

C6: The sentence was reformulated and "hinders" changed to "restricted"

C7: I agree and revised the sentence accordingly.

Details

The suggestions were considered and when necessary the manuscript was edited accordingly.

Response to the Interactive Comment by Anonymous Referee #2 (10th Oct, 2010)

The main points raised by the Referee #2 considered the footprint description and data quality control. As suggested, I added a reference to the footprint quality study of Göckede et al. (2008). It is also now mentioned in the text (section 2.2) that fluxes during stable stratification (winter in particular) should be interpreted with care, both because of footprint heterogeneity and instrument related problems. Based on cur-

rent knowledge it is, however, difficult to evaluate the specific effect of the oblong Lake Pitkäjärvi located ca. 700 m west-southwest from the tower on the wintertime fluxes. The ice covered period extends at least from late Nov – early Dec to mid-April and therefore evaporation from the lake is negligible and the surface characteristics resemble any plain snow covered surface. During snow-free season clear majority of evapotranspiration (and sensible heat exchange) takes place in daytime and heterogeneities in footprint in stable stratification are unlikely to significantly affect the results. Also, as noted by Göckede et al. (2008) the footprint heterogeneity is a minor issue when studying inter-annual variability as long the characteristics are not markedly altered during the analysis period.

The data quality was controlled in several steps. First, the EC system is monitored continuously by the permanent technical staff at the station and problems associated to e.g. abrupt calibrations shifts of gas-analyzer and Sonic freezing are detected. Secondly, the raw data is de-spiked prior flux calculations and periods when any spikes exist are rejected. After flux calculations and necessary co-spectral corrections etc. are performed according to Aubinet et al. (2000), the fluxes are filtered using empirical criteria based on knowledge from the site and its instrumentation. These empirical criteria include e.g. physically defensible limits for normalized standard deviations (σi/U, σT/T, etc.) and limits for maximum correlation between vertical wind speed and Licor sample temperature and pressure, which all reflect the technical performance of the EC setup. The role of Mr. Petri Keronen has been significant for maintaining the EC measurements and developing the on-site and post-field data quality control routine. The common practice of Micromet. Group in University of Helsinki, as in this study, has been not to apply micrometeorological quality criteria (beyond u*-filtering for some CO2 studies) for Hyytiälä site. Several quality indicators based on micrometerological theory (e.g. Foken and Wichura, 1996) are however routinely calculated and the role of each quality criteria filtering the data in Hyytiälä has been investigated (unpublished study). The quite obvious result from the analysis pertinent to this study was that the near-zero fluxes in stable conditions (e.g. nighttime LE) and fluxes during the transition periods are most often screened by the micrometeorological criteria. Considering ensemble averaged data or annual balances, the net effect of data filtering using these criteria is small (<5% on cumulative terms). The main interest in this study was on describing typical behavior and range of seasonal and inter-annual variability of energy exchange and "big-leaf" stomatal conductance and in this respect the "absolute" 1/2 h values have smaller importance and their uncertainty does not change the final conclusions. Rannik et al. (2006) studied uncertainty of measuring and modeling net ecosystem exchange at Hyytiälä using data from two EC setups separated horizontally by around 40 m. Their main conclusion was that annual NEE uncertainty $\sim$80 gCm-2 ($\sim$30% of mean annual NEE) between the two EC setups is mainly caused by daytime observations and is related to the variation of flow field over the complex topography than forest heterogeneities. Such a study has not been made for energy fluxes but rather similar effects can be expected and should be analyzed in future research.

I am reluctant to expand the already lengthy paper (as noted by Dr. Eugster in his review) to include more details on uncertainty analysis and quality control since the focus of the study is on inter-annual and seasonal variability and in this respect harmonized methods over the study period are more essential.

I also prefer to keep energy balance results (3.1) as separate chapter and present them first. In my opinion this improves the flow of the MS allowing direct transition from climate conditions to surface fluxes and their physiological and physical controls.

The comment on classifying the Hyytiälä site in respect of other FluxNet –sites is a good point and therefore I have added more details in Introduction. I feel this helps the reader to generalize the results from Hyytiälä to other evergreen needle-leaf forests on boreal region. The details include typical annual GPP, TER and water use efficiency and their relation to other sites of same vegetation type.

References

Foken T., and Wichura B.: Tools for quality assessment of surface-based flux measure-

ments. Agric. For. Meteorol., 78: 83-105, 1996.

Göckede M., et al.: Quality control of CarboEurope flux data – Part 1: Coupling footprint analyses with flux data quality assessment to evaluate sites in forest ecosystems. Biogeoscience, 5: 433-450.

McNaughton K.G. and Spriggs T.W.: An evaluation of the Priestley and Taylor equation and the complementary relationship using results from a mixed-layer model of the convective boundary layer. Estimation of Areal Evaporations (Proceedings of a workshop held at Vancouver, B.C., Canada) IAHS Publ. no. 177. 1989

Priestley C.H.B. and Taylor R.J.: On the assessment of surface heat flux and evaporation using large-scale parameters. Mon. Weather. Rev. 100: 81-92, 1972.

Rannik Ü., Kolari P., Vesala T. and Hari P. Uncertainties in measurement and modeling of net ecosystem exchange of a forest. Agric. For. Meteorol., 138;244-257.

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