Geophysical Research Abstracts
Vol. 15, EGU2013-5409-2, 2013
EGU General Assembly 2013

Low level jets and above-canopy drainage as cause of turbulent exchange in complex terrain during nighttime

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Estimating nighttime fluxes in complex terrain is still one of the most challenging tasks in the field of eddy covariance. This work focuses on low level jets (LLJ) and above-canopy drainage flows (ACDF), that are major causes of turbulent nighttime fluxes in complex terrain. Their effects on eddy covariance measurements are quantified and problems for nighttime flux estimates will be highlighted.
A combination of two eddy covariance set-ups together with SODAR and profile measurements of CO_2 and H_2O was used to understand the origin and the effects of nighttime turbulent exchange in complex terrain above a forest stand in Taiwan (Chilan site). The SODAR measurements reaching up to 300 m with a vertical resolution of 5 m showed that local wind maxima occasionally occur directly above the canopy (drainage flow), or at heights of about 100 to 200 m above ground (LLJ). Such LLJ regularly cause a drag that reaches down into the canopy and causes strong turbulence there. The ACDF also produces strong turbulence, and a drag can be observed that influences the wind field up to 60 m above the canopy. Both LLJ and ACDF are not steady throughout the nights but last for periods of 30 minutes to 3 hours. They seem to be caused by atmospheric instabilities because they appear within 10 minutes throughout the vertical profile and, later, disappear equally quick. During their occurrence they have a strong influence on the vertical turbulent exchange between the forest and the atmosphere. This is shown by eddy covariance data and the profiles of CO_2 and H_2O. E.g., strong CO_2 gradients are built up during the early night due to accumulation of CO_2 within and below the canopy as a result of nighttime respiration. As turbulence enters the canopy and trunk space, CO_2 is transported out of the forest into the atmosphere. As a result, the vertical gradients between the canopy and the atmosphere attenuate and almost disappear within 30 minutes. During such periods with increased turbulence due to LLJ and ACDF, 30 – 40 % of the total turbulent night time fluxes are generated even though these periods only account for 5 – 30 % of the nighttime period. High turbulence periods are more likely to fulfill quality criteria (stationarity or u*) than periods with less turbulence. At sites where LLJ and ACDF occur frequently this can lead to a systematic overestimation of nighttime fluxes.