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Vertical and horizontal transport of energy and matter by coherent motions in a tall spruce canopy

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In a forested ecosystem low frequency coherent events contribute significantly to the budgets of momentum, heat and matter. In the frame of EGER (ExchanGE processes in mountainous Regions) project the contribution of coherent structures to the vertical and horizontal transfer of energy and matter in a tall spruce canopy was investigated. Two measuring campaigns were carried out in North-Eastern Bavaria at the Waldstein site in the Fichtelgebirge mountains. Observations of coherent structures were obtained by a vertical profile of sonic anemometers equipped with fast CO_2 and H_2O analyzers covering all parts of the forest up to the lower part of the roughness sub layer. In addition five small masts were set up in the trunk space of the forest and equipped with sonic anemometers, humidity and temperature sensors as well as CO_2 analyzers. Combination of measurements done in vertical and horizontal directions allows us to investigate coherent structures, their temporal scales, their role in flux transport and vertical coupling between the subcanopy, canopy and air above the canopy level.
To extract coherent structures from the turbulent time series, the technique based on the wavelet transform has been used. Conditional sampling analysis showed a domination of coherent structure signatures in vertical wind measurements with probable temporal scales in the order of 10 s to 30 s. The mean temporal scale of coherent structures detected in the trunk space of the forest was 30 - 40 s. The number of coherent structures detected at the slim and tall tower was found to be 40% less than the number of coherent structures detected at the heavy main tower. In contrast to the slim tower the main tower is more massive and was equipped with more instruments resulting for additional generation of turbulence.
The Reynolds-averaged flux and flux contribution of coherent structures were derived using a triple decomposition for the detected and conditionally averaged time series, when coherent structures were present. The analysis shows dominant momentum and sensible heat transport by coherent structures in the canopy space. Carbon dioxide and latent heat transport by coherent structures increases with height within the canopy and reaches a maximum at the upper canopy level. The flux contribution of the ejection phase decreases with increasing height within the canopy and becomes dominant above the canopy level. The flux fraction transported during the downward directed sweep phase increases with height within the canopy and becomes the dominating exchange process at the upper canopy level. Close to the ground surface in the subcanopy space, ejection and sweep phase contribute equally to the flux transport.
The determined exchange regimes indicate consistent decoupling between trunk space, canopy, air above the canopy during evening, night and morning hours. Entire coupling between all canopy levels and trunk space of the forest was observed around noon.