Geophysical Research Abstracts
Vol. 20, EGU2018-4226, 2018
EGU General Assembly 2018

Analysis of wind-induced air pressure fluctuations responsible for pressure-pumping in a Scots pine forest

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Exchange of greenhouse gases between the atmosphere and the soil is highly relevant for the climate of the Earth. While it is commonly assumed that gas transport in the soil is governed by molecular diffusion, it is increased through additional processes during periods of strong wind. This increase cannot be produced directly by atmospheric turbulence, since turbulence elements cannot penetrate through the surface. Therefore, wind-induced air pressure fluctuations are assumed to cause an increase in soil gas transport. The characteristics of the air pressure fluctuations associated with the pressure-pumping effect are crucial for the quantification of the strength of the pressure-pumping.

To investigate the pressure-pumping effect in the field, airflow, air pressure and soil gas transport measurements were conducted in the Scots pine forest of the meteorological measurement site in Hartheim, Germany.

The occurrence of air pressure fluctuations associated with pressure-pumping shows a strong dependence on above-canopy wind speed. Moreover, results showed that the propagation speed of air pressure fluctuations are similar to the above-canopy wind speed. The direction of propagation of air pressure fluctuations also correlates well with the above-canopy wind direction. These results emphasize the statistical relation between the strength of the pressure-pumping effect and above-canopy airflow. Furthermore, it was shown that the pressure-pumping coefficient stays nearly constant over a spatial extent of 90 m. Analysis of the soil gas transport measurements could show that pressure-pumping influences the soil gas concentration in the topsoil and leads to an increase of the soil gas diffusion coefficient of up to 40 %.

Thus, for the first time, the pressure-pumping effect could be observed in the field and the relevant air pressure fluctuations could be characterized.