



Contribution ID: 15

Type: **Poster + 3 Minute Pitch**

Wind-induced soil-atmosphere gas exchange as related to near-surface wind speed characteristics and soil physical properties

Monday, 14 May 2018 15:37 (2 minutes)

Mechanisms of pore gas transport and exchange across the porous medium-atmosphere interface in wind-exposed porous media was investigated for a range of porous media under different near-surface wind conditions.

Four dry porous media with mean particle diameters of 1.6, 2.0, 4.2 and 10.5 mm were used. These relatively coarse materials were selected, to facilitate easier identification of the parameters governing wind-induced porous medium gas transport and exchange with the atmosphere. Cylindrical porous medium samples 25 cm in diameter and thickness ranging between 15 and 35 cm were used.

Experiments were carried out under controlled conditions for 10 different wind conditions with respect to wind direction, wind speed magnitude and wind speed variability yielding 40 combinations of porous medium and wind condition. Average resultant wind speed as measured 4-12 cm above the porous medium surface ranged between 0.5 and 3 m/s.

Tracer (air and CO₂) gas breakthrough curves were measured at five depths within each sample. A total of 400 individual tracer gas breakthrough curves (including replicates) were produced.

Porous medium gas transport and exchange with the atmosphere was approximated as a one-dimensional dispersive/diffusive process with a depth-dependent dispersion coefficient (D_w). Two models for describing the depth – D_w relationship using two and three empirical fitting parameters, respectively, were evaluated. For each combination of porous medium and wind condition, fitting parameters were determined by numerically solving the dispersion equation (with D_w described by either of the two models), while fitting the solution to all five tracer breakthrough curves simultaneously. In all cases both models yielded close fits to measured breakthrough data.

Results showed that in addition to porous medium depth (or distance to the wind-exposed surface), D_w (and thus, gas transport and exchange) was strongly dependent on both mean wind speed, and wind speed power spectrum characteristics, indicating that not only mean wind speed, but also wind gustiness is important. Results further showed that porous medium particle size and to a lesser degree also hydraulic conductivity and air permeability correlated significantly with gas transport and exchange (D_w).

References

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Session Classification: Parallel 2-F

Track Classification: MS 1.19: Interface driven processes in porous media