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Impact of wind speed and soil permeability on gas transport in the upper vadose zone

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In high permeability soils, the overall gas flux through the Earth-atmosphere interface can be significantly greater than the diffusive gas flux. One mechanism that can contribute to the overall flux increase is wind-induced transport (WIT). Development of WIT is directly affected by soil properties (mostly soil permeability), as well as by wind properties, such as wind speed. Here, we explored the development and classification of WIT as a function of averaged wind speed and porous media permeability (i.e. soil and soil aggregates). Five columns, each filled with homogeneous dry porous media with different permeability, were installed in a bare field. The soil permeabilities ranged from sand (3.87*10-10 m2) to large aggregates collected from a nearby agricultural field (2.67*10-6 m2). CO_2-enriched air was applied to the bottom of the columns and was used to quantify the ventilation time in each column. Measurements were carried out under natural wind conditions. Data collected included atmospheric (wind speed, air temperature, barometric pressure, etc.) and porous media parameters inside the columns (temperatures and CO_2 concentration at depth of -0.2 m). Data from the CO_2 concentration variation in the experiment were compared to: (1) an analytical diffusion transport solution; and (2) a numerical advection-dispersion solution. Results show that in the low permeability sand, gas transport was governed by diffusion with a small additional WIT effect, increasing total transport by up to $\sim$15% for cases of high wind speed (>5 m/s). At all permeabilities above that of gravel ($\geq$ 1.02*10-8 m2), WIT dominated gas transport, and the effect of WIT was up to one order of magnitude greater than diffusion even under low wind speeds ($\sim$2 m/s).